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ABSTRACT

Teachers, supervisors, and teacher educators who participated in the 1968 NDEA Title XI Institute developed experiments and instructional units to be used by industrial arts and technical education teachers. The program involved a study and development of industrial materials, field testing, and the preparation of transparencies and slides. The first volume contains two general units on elements and structure of matter, 14 units covering various properties of metal, and 10 units on forest products. Each unit gives instructional level, title, and presentation time, and most units outline objectives, inter-relationship with other subjects, use in industry, materials and equipment, educational media, utilization in the teaching-learning environment, definition of terms, evaluation and observation methods, and references. Transparency masters are included and information for purchasing the 63-slide and narrative presentation is available from the Industrial Studies Department at San Jose State College. Volume II is available as VT 008 295. [Not available in hard copy due to marginal legibility of original document.] (GR)

C.1

INSTRUCTIONAL UNITS

for

INDUSTRIAL MATERIALS

ED039314

Prepared by: Industrial Arts Educators
attending the
NDEA Title XI Institute for
Advanced Study in Industrial Arts

San Jose State College
San Jose, California
June 24-August 2, 1968

VOLUME I OF TWO VOLUMES

(Contains Information up to and including Forest Products as listed in the following Table of Contents.)

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FOREWARD

The instructional units included in this publication were prepared by the teachers, supervisors and the teacher educators in attendance at the NDEA Title XI Institute in Industrial Materials conducted on the San Jose State College campus from June 24 to August 2, 1968.

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The program involved four phases. The first phase consisted of a concentrated study of Industrial Materials as content for the various subjects within Industrial Arts. The emphasis was on the integration of Industrial Materials as a part of the existing program, rather than the establishment of new ones.

The second phase consisted of the development of instructional units which, with the use of common audio-visual aids, could be easily implemented in present Industrial Arts programs. The individual and group efforts have been brought together and are presented in the following pages. Major areas have been identified and, in some cases, a general preview is presented prior to the units. The units shown are a result of specific interest of the participant and are only a sampling of units which could be developed for the inclusion of Industrial Materials in the present Industrial Arts curriculum offerings.

The third phase consisted of field testing the developed units in the summer program of secondary schools in the San Jose area. This provided valuable information relating to the ability of students to profit from the organized study of Industrial Materials.

The fourth phase provided general information on new developments in instructional media. This phase led to the preparation of transparencies and slides included with many of the units.

Some of the original units were edited to reduce their size. Budget limitations prevented the complete duplication of all units.

Following most units are offset copies of drawings developed for overhead transparencies. These may be removed and used to produce transparencies through the use of duplicating facilities available in most school districts. We encourage each user to prepare his own transparencies. Use of food coloring or paste on colored materials can improve the transparencies and make them more valuable for classroom use. Enclosed also, is a film list.

A number of the units had slides prepared for use with the presentation. If you are interested, copies of the slides can be purchased. Details for purchasing are available from the Industrial Studies Department at San Jose State College.

ACKNOWLEDGEMENTS

The following units were developed by the participants under the direction of the faculty with their supporting assistants and staff.

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GENERAL

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Alfred J. Slowe
North Attleboro High
North Attleboro, Massachusetts

INSTRUCTIONAL LEVEL: High School

TITLE: A Periodic Chart of the Elements. Long Form

PRESENTATION TIME: 1 hour

INTRODUCTION:

The greatest rewards of our studies can perhaps be found in an understanding of atomic structure and its part in shaping man's future. It is hoped that this periodic chart of the elements and its accompanying tables will aid in our future studies of atomic and molecular structures as they apply to industrial materials.

The periodic chart of the elements can be referred to as a "Natural Classification of the Elements." It is natural because it is based upon certain fundamental characteristics of the atoms of the different elements. It is periodic because elements with similar properties appear at regular intervals in the arrangement.

OBJECTIVES:

To acquaint the students with this particular version of the periodic chart of the elements and its accompanying tables.

To point out to the students what types of information can be obtained from the chart both directly and indirectly.

INTER-RELATION WITH OTHER SUBJECTS:

This unit is designed to be a basic unit for all industrial materials areas--wood, metal, plastics, polymers, etc.

It is a unit which could be used both in the industrial materials and science areas. Some students may have covered all this material before. For them it will serve as a reinforcement of their prior learnings.

USE IN INDUSTRY:

This chart is used in industry as a handy reference source of atomic structure, weights, activity of elements, how atoms react with atoms of other elements, etc.

MATERIALS AND EQUIPMENT:
No special materials or equipment are necessary.

EDUCATIONAL MEDIA:
Prepared transparencies
Notebook size periodic chart for each student
Wall periodic chart of the elements

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:
No safety precautions are needed.

PRESENTATION:
Periodic Chart of the Elements, Long Form

I. Introduction
II. Transparency 1
   A. Chemical Symbol - a chemical abbreviation of an element. This symbol can be a single letter as H for hydrogen or two letters as Zn for zinc. A single-letter symbol is always capitalized. In a two-letter symbol, only the first letter is capitalized.
   B. Atomic Number - shown above the symbol for each of the elements. The atomic number is the number of protons or total positive charge in the nucleus of the atom. In a neutral atom the total number of protons would also be equal to the total number of negative electrons. The atomic number governs the structure and behavior of the atom.
   C. Atomic Weight - given below each element shown. This is an average weight, in atomic mass units, based upon the standard of carbon being 12,000. The atoms of a given element may differ in weight as much as ten percent without appreciably altering their properties. Chemically these atoms appear identical.
   D. Electron Configuration - To the left of each element is shown the electron configuration of the shells, for instance, Potassium, chemical symbol K, has 2 electrons in the K shell, 8 electrons in the L shell, 8 electrons in the M shell and 1 electron in the N shell.
   E. Neutrons - The number of neutrons in the nucleus can be obtained by subtracting the atomic number from the atomic weight. For example, Potassium,

symbol K, atomic number 19, atomic weight 39 would have 20 neutrons in the nucleus of the atom (39-20).

III. Transparency 2
   A. Quantum Numbers - The principal quantum number, designated by the letter "n" has values of 1 to 7, corresponding to the K, L, M, N, O, P, and Q shells of the atom. The size of the electron, the volume of the bulk of charge density, varies directly as the value of n.

IV. Transparency 3
   A. Subshells - the energy levels into which the principal shell or orbit is divisable into s, p, d, and f subshells. Electrons in the same subshell have similar amounts of energy.

      The brackets indicate the general order of subshell filling.

      The use of red ink denotes shells which have electron populations different from the preceding element.

V. Transparency 4
   A. Inert Gases - all have filled outer shells and this is a very stable arrangement. These atoms show almost no chemical activity. They are found in a vertical column at the far right of the chart.

VI. Transparency 5
   A. Metalloids - are elements which show characteristic properties of both metals and nonmetals. Most metalloids have physical properties characteristic of metals. Seven elements are usually called metalloids: boron, silicon, germanium, arsenic, antimony, tellurium, and astatine. These metalloids are located adjacent to steps on the periodic table as shown on this transparency.

VII. Transparency 6
   A. Period or Series of elements is the name given to each horizontal row of elements. In going from left to right in any period or series, the elements become less metallic and more nonmetallic. Elements near the left end of a period have a greater tendency to form negative ions with the last element an inert gas.

      A period of elements starts at the left with an element that has a single electron in its valence shell and ends at the right with an inert gas with eight electrons in the outer shell.

B. Family or Group is a vertical column of elements. Elements in a given family are similar and their properties vary from top to bottom. Elements in a vertical group have similar electron structures, and therefore similar properties, particularly with regard to valence.

C. Electronegativity - the attraction that an atom shows for electrons while that atom exists in a covalent bond.

Electronegativity increases from bottom to top in families and from left to right in periods of elements.

D. Metallic Properties - increase from the upper right hand corner of the chart to the lower left hand corner of the chart. Fluorine would be the most reactive nonmetal.

Cesium and Francium, located in the lower left of the chart are the most reactive metals.

VIII. Transparency 7

A. Valences, the combining power of an atom are shown in a table just below the Periodic Chart. Solid circles report the more common valence states of the elements. Open circles represent valence states of minor importance.

IX. Transparency 8

A. Electromotive Series - a list of reducing agents arranged in decreasing order with respect to reducing ability. Elements in this series are so arranged that their standard electrode potentials vary from most positive to most negative. The series places the more active metals higher in the list, activity being considered in connection with reactions in a water medium. Also called activity series and electromotive series.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

After each point persented to the students, examples will be given by the teacher followed by questions to the class concerning the point. For instance, after presenting transparency one and explaining atomic number and atomic weight, a question might be, "how many protons, electrons and neutrons are there in a neutral atom of Sodium. Student performance would be measured in this way.

UNIT EVALUATION:

Unit evaluation would be made by means of the enclosed test.

DEFINITION OF TERMS:

1. Activity Series - a list of reducing agents arranged in decreasing order with respect to reducing ability.
2. Atomic Mass - the exact mass of an atom in atomic mass units. The standard for such units is the isotope carbon-12, which is assigned a mass of exactly 12 atomic mass units.
3. Atomic Number - the number of protons (total positive charge) in the nucleus of an atom.
4. Atomic Weight - the weight assigned to an element in atomic mass units, considering the standard for atomic weights to be based on carbon with a weight of 12,000.
5. Covalent Bond - a bond indicating a pair of shared electrons.
6. Electromotive Series - a list of reducing agents arranged in decreasing order with respect to reducing ability.
7. Electrochemical Series - a list of reducing agents arranged in decreasing order with respect to reducing ability.
8. Electron - the unit of negative electricity.
9. Electronegativity - the attraction that an atom shows for electrons while this atom exists in a covalent bond.
10. Energy Levels - the parts of the atom to which orbital electrons are restricted.
11. Family - a vertical column of elements in the Periodic Table.
12. Inert Gas - one which has its outer shell of electrons filled, a very stable arrangement. These atoms show almost no chemical activity.
13. Ion - an atom or group of atoms with a negative or positive charge.
14. Metalloid - an element which shows characteristics of both metals and nonmetals.
15. Neutron - the neutral particle found in the nucleus.
16. Period - a horizontal sequence of the Periodic Table, from alkali metal to inert gas.
17. Periodic Table - an arrangement of the elements in the order of increasing nuclear charge.
18. Proton - the fundamental, positively charged particle, present in the nucleus of all atoms.

19. Quantum Number n - has the values 1 to 7, corresponding to the K, L, M, N, O, P, and Q shells of the atom. The size of the electron or the volume of the bulk of charge density, varies directly as the value of n.
20. Series - a horizontal row of elements in the periodic table, from alkali metal to inert gas.
21. Shells - a region in the atom in which electrons of similar energies are apt to be found. Electrons in the same shell are approximately the same distance from the nucleus.
22. Sub-energy Levels - the energy levels into which the principle shell or orbit is divisible.
23. Subshells - the energy levels into which the principle shell or orbit is divisible.
24. Symbol - one or two letters used to designate one atom of an element.
25. Transition Element - one of a group of metals which have an incomplete subshell of electrons located in one of the inner shells.
26. Valence - the combining power of an element, equal to the number of atoms of a univalent element with which one of its atoms can combine.

REFERENCES:

STUDENT

Dorin, Henry, Vitalized Chemistry, 1966, New York College Entrance Book Company.

TEACHER

Dorin, Henry, Vitalized Chemistry, 1966, New York College Entrance Book Company.

H. G. Deming, Fundamental Chemistry, John Wiley and Sons, Inc.

UNIT TEST

PERIODIC TABLE

1. The elements found at the bottom of a family in the Periodic Table are generally (metals, nonmetals).

2. Elements grouped together vertically in the Periodic Table constitute a chemical ___________.

3. In passing from left to right through the elements of the third period, the elements become less ___________ and more ___________.

4. Electronegativity increases as the number of valence electrons ______________.

5. The number of electrons in the outer shell of the elements in Group II of the Periodic Table is (1) 1 (2) 2 (3) 3 (4) 4.

6. Argon and Potassium are correctly placed in the Periodic Table when they are arranged according to their (1) atomic diameters (2) atomic weights (3) mass numbers (4) atomic numbers.

7. Sodium and Potassium belong to the same chemical family because (1) they are very active (2) their names have the same ending (3) they are stored under Kerosene (4) their atoms have one valence electron.

8. An example of an inert element is the element with atomic number (1) 4 (2) 8 (3) 10 (4) 20.

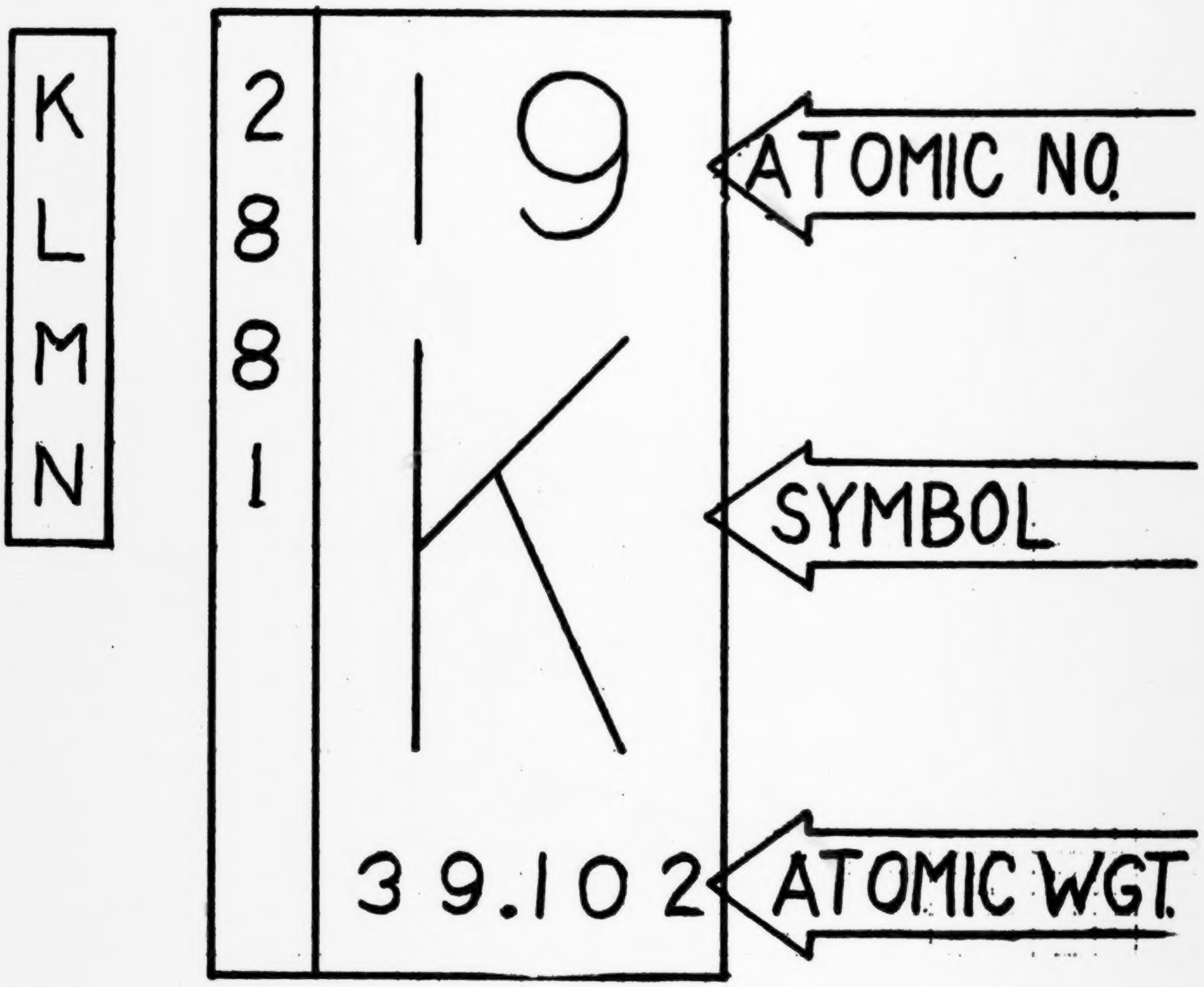
9. The elements in the Modern Periodic Table are arranged according to the (1) atomic weights (2) number of protons in the nuclei (3) number of neutrons in the nuclei (4) masses of the isotopes.

10. Compared with the neon atom, the sodium ion has the same number of (1) electrons (2) protons (3) neutrons (4) excess positive charges.

11. The most electronegative element is (1) oxygen (2) sodium (3) fluorine (4) chlorine.

12. The element with atomic number 6 is in the same chemical family as the element with atomic number (1) 4 (2) 10 (3) 14 (4) 22

13. Describe in detail the structure of the Zinc atom.


K
L
M
N
2
8
8
1
19
K
39.102
ATOMIC NO.
SYMBOL
ATOMIC WGT.

SHELLS

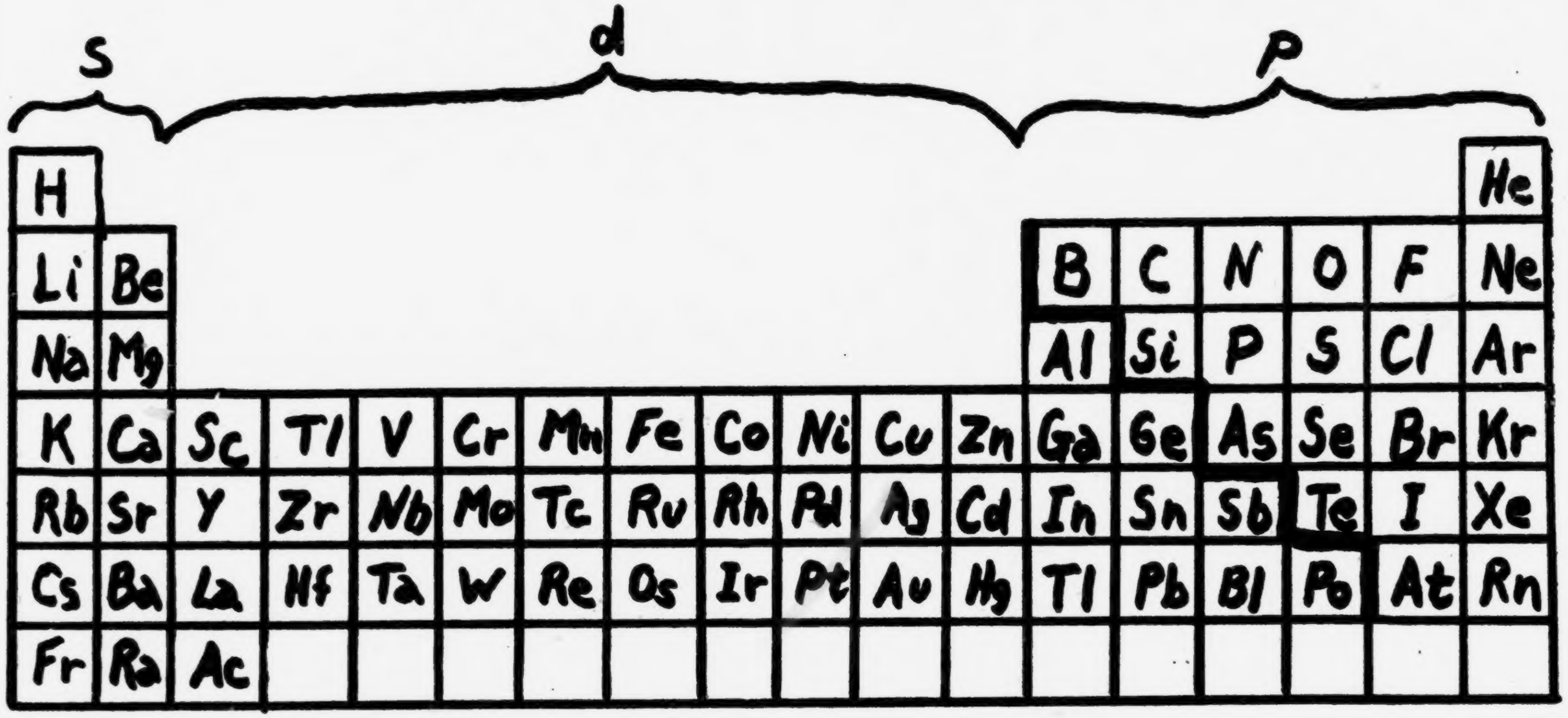
PRINCIPAL QUANTUM NO. n	X-RAY NOTATION	
1	K	2
2	L	8
3	M	18
4	N	18
5	O	4
6	P	
7	Q	

50

Sn

119.

Subshell Grouping



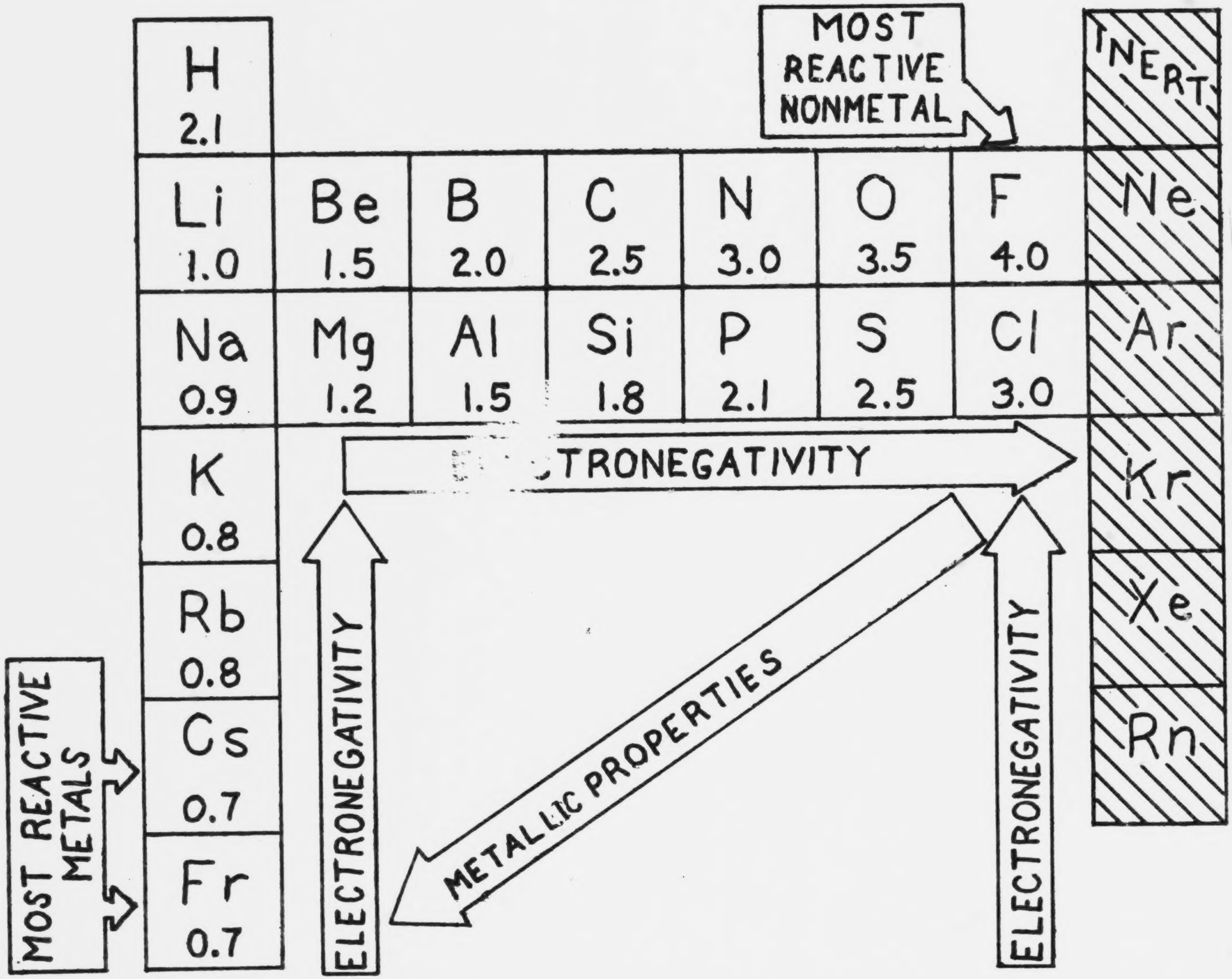
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

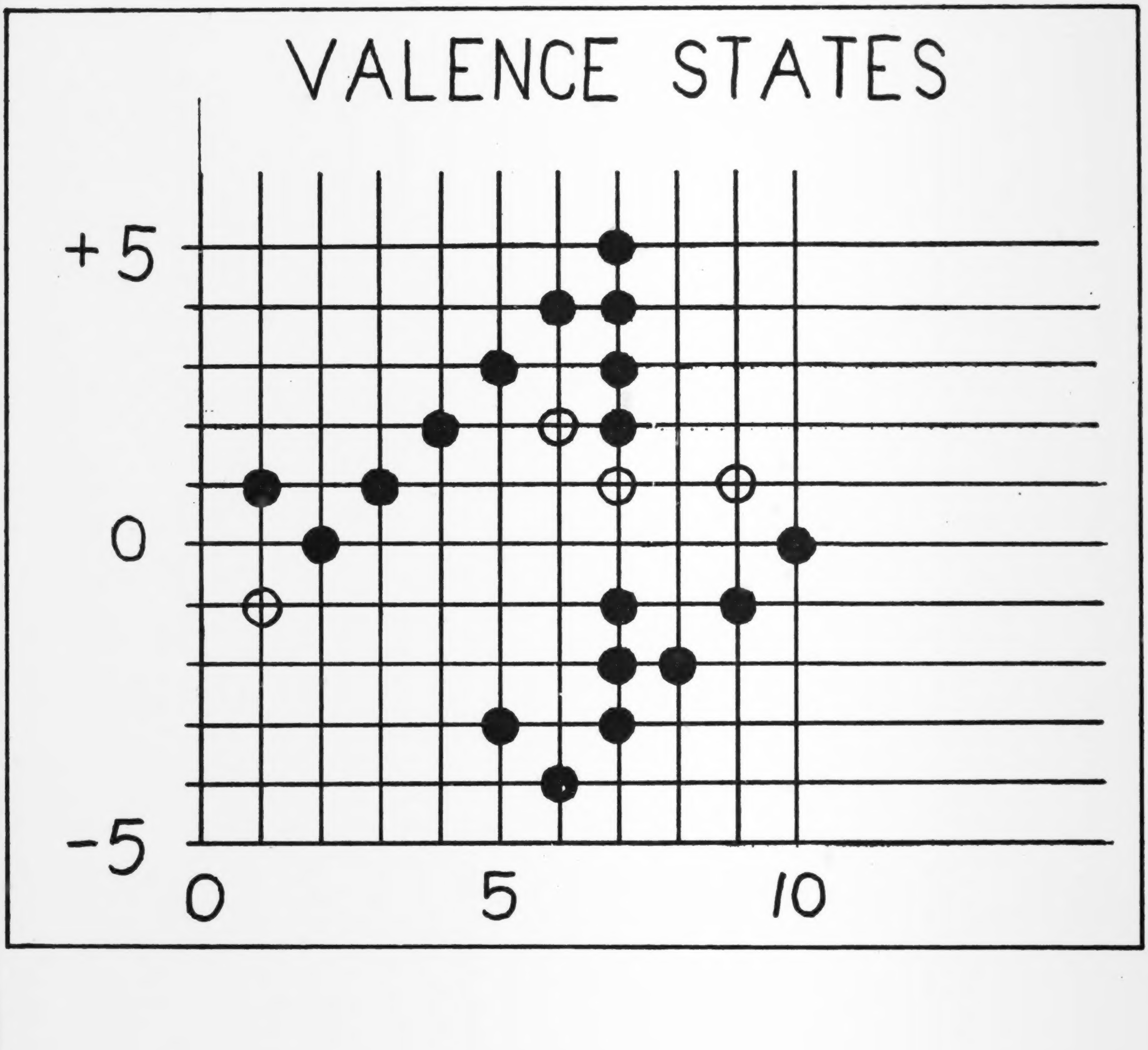
INERT
GASES

2	He
2 8	Ne
2 8 8	Ar
2 8 18 8	Kr
2 8 18 18 8	Xe
2 8 18 32 18 8	Rn

Metalloids

IIIA	IVA	VA	VIA	VIIA	
B					
	Si				
	Ge	As			
		Sb	Te		
				At	


MOST REACTIVE NONMETAL
INERT
H 2.1
Li 1.0
Be 1.5
B 2.0
C 2.5
N 3.0
O 3.5
F 4.0
Ne
Na 0.9
Mg 1.2
Al 1.5
Si 1.8
P 2.1
S 2.5
Cl 3.0
Ar
K 0.8
ELECTRONEGATIVITY
Kr
Rb 0.8
Xe
Cs 0.7
Rn
Fr 0.7
MOST REACTIVE METALS
ELECTRONEGATIVITY
METALLIC PROPERTIES
ELECTRONEGATIVITY


VALENCE STATES
+5
0
-5
0
5
10

ELECTROMOTIVE SERIES

TENDENCY TO OXIDIZED STATE ↑

TENDENCY TO REDUCED STATE ↓

REDUCTANT		OXIDANT	POTENTIAL
Ca	$\rightleftharpoons$	Ca^{++}	+2.87
Al	$\rightleftharpoons$	Al^{+++}	+1.66
Sn	$\rightleftharpoons$	Sn^{++}	+0.14
H	$\rightleftharpoons$	H^{+}	0.00
Cu	$\rightleftharpoons$	Cu^{++}	−0.34
Fe^{++}	$\rightleftharpoons$	Fe^{+++}	−0.77
Br^{-}	$\rightleftharpoons$	Br_2	−1.07

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: John C. McCollum
Homestead High School
Sunnyvale, California

INSTRUCTIONAL LEVEL: High School (with adaptations it can serve the junior high school and the college levels)

TITLE: The Structure of Matter

PRESENTATION TIME: 10 hours

INTRODUCTION:

Matter is anything that takes up space or has mass. The earth, the atmosphere, the heavenly bodies, wood, metal, plastics (polymers), lubricants, and fuels are examples of matter.

Energy is the ability to do work. Every action in nature involves energy. The energy of a system is that system's ability to do work. The growth of a tree, the shaping of a metal, or the mere washing of a car require the use of energy. The forms of energy are agencies with which work is accomplished, and these forms are heat, light, electrical, chemical, mechanical and atomic. Potential energy may be thought of as the energy a body possesses because of its position, such as a brick resting high on a building ready to be converted into kinetic energy by virtue of its motion of falling. Radiant energy (electromagnetic radiation) is the type of energy associated with light, heat, radio waves, X-rays, etc. Radiant energy from the sun is transformed by a living plant into chemical energy.

From the study of physics and chemistry, the technologist discovers that matter and energy of all forms are related to each other. The scientists believe that the only thing that is taking place in this world of matter is a transformation of matter into energy and of energy from one form to another. The atomic bomb is proof that matter can be transformed into energy and today an atom of material represents a vast new storehouse of energy.

Through chemistry a student studies the changes which matter undergoes and he finds that in every chemical reaction energy in some form is added or released. Whether he specializes in home economics, biology, industrial arts, or a field of engineering, the learner will find himself studying chemical processes to some degree. Unless he understands the nature and structure of matter, he is not capable of making an intelligent application and use of the various forms of matter available to man for his comfort and pleasure. These items of matter may be grouped together under a general title of "industrial materials."

The conversion of materials into useful products requires the application of energy to bring about the desired qualities in an object, e.g. heat treatment of steel, or those as complex as an automobile. Quite often this conversion of materials into useful products is accomplished by the use of electricity. On the other hand, more and more products, from toys to computers, consume electricity in their operation. Since electricity is a flow of electrons, passed from atom to atom in certain types of materials, it too is a part of matter and should be included as a basic part of the concepts thereof.

Because electrons are one of the building blocks of matter they are involved in every chemical reaction. The electrons and the nucleus of the atom are the forces which bind atoms together into molecules to create such things as wood, fuels, metals, polymers, etc. Chemical reactions occur by electron transfer or a sharing of electrons with an exchange of energy. Also, energy may be put into the electrons' energy levels and when it is released we can observe it as an electromagnetic radiation called light or heat. An application of this phenomenon has provided a new industrial product called LASERS, which are performing all kinds of tasks previously considered impossible. Radio waves (another form of electromagnetic radiation) can be generated by a rapid movement of electrons back and forth in a conductor made of copper. Thus, the full understanding of materials must include the study of the atom itself if we are to understand how it behaves and what it can do in the myriad of combinations we know as industrial materials and power.

OBJECTIVE:

To develop an understanding of the structure of matter as it relates to industrial materials, technical processes and the common forms of energy.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: All subject areas of industrial arts.

INTER-RELATION WITH OTHER SUBJECTS:

This unit can be used as the beginning unit (or at a more suitable time, in full or in part) of woods, metals, automotive mechanics, power mechanics, electricity/electronics, and polymer courses. It will provide for the teaching of basic concepts for electrical systems of electronic devices or automobiles, prevention of corrosion of metals, arc welding, manufacture of plastics, bonding agents for woods and metals, chemistry, and physics to name but a few. For example the oxidation of fuels during combustion is not unlike the corrosion of steels, since the latter is also oxidation with a much slower release of energy. Properly applied the rusting of iron can develop feeble amounts of electric power.

USE IN INDUSTRY:

We live in a technical age. Everything we use, wear, or travel in is made possible as the result of our technological development. Every student will come into contact with the products of industry and he must receive an adequate understanding of the principles underlying his technology. However, the very complexity of the technical culture makes it impossible to impart all of the knowledge that has become available. Therefore, the approach must be to develop those fundamental concepts of industry that remain essentially unchanging and upon which he can build and adapt to a changing technology. The structure of matter can be viewed as one of the basic concepts which is essential for his functioning in industry.

MATERIALS AND EQUIPMENT:

- Per Student -
    - Vacuum Tube Voltmeter
    - Milliammeter
    - Metal
        - Copper strips 1/2" x 4"
        - Iron strips 1/2" x 4"
        - Zinc strips 1/2" x 4"
    - Sand - teaspoon
    - Tap water

EDUCATIONAL MEDIA:

- Films
    - Chemical Bond and Atomic Structure
    - Ionization (#1847)

(Both films may be obtained from:
Craig Corporation (Coronet Films)
3410 S. La Cienega Blvd.
Los Angeles, California 90016)

Overhead Projector

UTILIZATION IN TEACHING-LEARNING ENVIRONMENT:

SAFETY: Only standard laboratory safety procedures are required in the presentation of this unit.

PRESENTATION:

I. The Atomic Structure
   A. The atom
      1. Electron
      2. Nucleus: Proton and neutron
      3. Law of repulsion and attraction (law of charges)
      4. Size and weight of particles
      5. Shells (energy levels) K through Q
      6. Atomic numbers (electron population)
      7. Valence, valence electrons
      8. Ions, positive and negative

   B. Elements
      1. Definition
      2. Numbers of elements
      3. Periodic Table (electron population)

II. Combinations of atoms
   A. Classes of matter
      1. Elements
      2. Molecules (compounds)
      3. Mixtures

III. Bonding of atoms to form molecules

The chemical bond is formally defined as the attractions between two atoms within a molecule, attractions in part electrical and in part magnetic. This attraction involves primarily the action of the valence electrons. A study of the valence can tell much about the structure of an atom, what it is most likely to combine with, etc.

Atoms of elements, other than those of the inert gases, would be more stable if they could somehow acquire eight electrons in their valence band (outer shell). Since this is a stable condition, it can be called a stable octet. Atoms enter chemical combinations to acquire a more stable configuration, i.e., iron will become stable after it reacts with oxygen to form our familiar rust (iron-oxide). The chemical combining we call reactions generally involves only the valence electrons, so the nucleus can be ignored although its composition is most important to us in other ways.

1. Positive electrovalence

   It is the number of electrons in the outer shell that an atom must lose to attain the stable octet.

2. Negative electrovalence

   It is the number of electrons in the outer shell that an atom must gain to attain the stable octet.

How atoms react to attract and hold other atoms is called bonding. There are three main types along with a weaker secondary type. These are:

1. Ionic (electrovalent) bonds

   A transfer of valence electrons from one atom to another, creating a positive and a negative ion which are then attracted to each other. In general, when a metallic element combines with a non-metallic element, electrons are lost by atoms of the metal and gained by the atoms of the non-metal. The transfer of electrons occurs by an exchange of valence electrons between the atoms involved. Thus, when we think of a "molecule" of table salt (sodium chloride--NaCl), we can think of a positive ion being held to the negative chlorine atom (ion) by simple electrostatic attraction of unlike charges.

2. Covalent bonds

   It is the number of electron pairs (double bonds) that are shared by the molecule and once they are formed, they bind an atom as if they were literally tied together. Examples of the bonding are: water, methane gas, carbon tetra-chloride. This type of bonding is used by many elements in a crystalline structure, e.g., silicon and germanium are grown as a crystal from which we manufacture transistors and the integrated circuits (microelectronic devices). Often the form of joining together results in an unequal distribution of the charges which become attractive forces.

   a. Distribution of the charge in a molecule
      There are several varieties of covalence, the chief being the following:

1) Nonpolar

When atoms combine, the charges are redistributed in the new material. If the redistribution in the molecule is such that the two kinds of charges have a common center, it is nonpolar.

2) Polar

If there is no common center, both the molecule and the bonds holding it are polar so that the distribution of the two charges (positive and negative) is asymmetrical. That is, one end of the molecule has a residue of a positive charge while the other is negative; in other words, a dipole is formed. The more asymmetrical the distribution of the charge, the more polar the molecule (or more attractive).

3. Metallic bonds

Solid metallic substances are not believed to exist as normal atoms. A metal is composed of a rigid crystalline structure of positive ions created by the intense thermal energy at the time of solidification. The ions are surrounded by their valence electrons which form a gas-like cloud of negative particles. While these electrons are restricted to certain energy levels, they have sufficient freedom so that they are not shared continuously by the same two positive ions. The arrangement of ions depends upon the establishment of equilibrium among all forces involved. The positive electric charges of the ions create repulsive forces between any pair of ions. Likewise, electrons with the negative charge are distributed fairly evenly throughout in the electron cloud. Between the positive ions and electrons there exists forces of attraction which bind the structure together. These forces are predominately electric in nature. Crystals and grains of metals consist of repetition of the unit cells which have the fundamental crystalline properties. When different grains grow until they stick others, the boundary becomes a stressed area and can be seen under a microscope.

Thermal energy (electromagnetic radiation) causes the ions to oscillate around their unit cell. Thus, the location of a particular ion actually represents an average position. Thermal vibration increases with rising temperatures which in turn increases the effective area of the vibrating ion. Therefore, the solid material increases its dimensions, causing expansion of the metal. When the melting point is reached, the violence of the ion movement is so great that the binding forces are broken, leaving a rather disordered liquid mass.

The high heat conductivity of metals is also accounted for by the metallic bond. When the end of a steel bar is heated, the electrons also move aobut more violently. Because the electrons are free to travel in the crystalline metal lattice, some of this energy can be transported quickly to atoms at the opposite end of the bar. Non-conductors of heat have few free electrons for the transmission of heat, which of necessity must move thorugh the atoms themselves at a much slower rate by bumping into each other.

Metallic bonding provides for other effects. The free electrons in the gas-like cloud are moved easily by magnetic and electric fields to create electricity by a flow of electrons, and secondly, they can absorb light energy. If the energy is insufficient to raise the electrons to their next energy level, there will be no visible effects of light being passed through the metal. It is somewhat similar to the color black which absorbs rather than reflects light. Therefore, we say that metal is opaque.

The strength and toughness of metals can be explained by their type of bonding structure. The positive ions can glide over one another rather easily, hence they do not give way in a complete fracture when the metal is hammered into thin sheets or drawn into wire. The interatomic attraction can be reduced by increasing the distances with increased thermal vibration by increasing temperatures. However, this effect is detrimental when metals are used at elevated temperatures for they suffer plastic deformation called creep when subjected to high stresses over extended periods of time. This amounts to a stretching of the metal and could result in the failure of a particular part or an entire unit, such as could happen when a connecting rod grew in length to allow a piston to strike the top of the cylinder and destroy an engine operating at very high speeds.

4. Van der Waals forces

The three types of bonds discussed above are all realtively strong bonds which hold most solids and liquids together. There are, however, other secondary forces called Van der Waals forces. These forces are so weak that they often times can be overlooked until the three major forces are eliminated. Weak as they are, they affect boiling points, vapor pressures, etc., and make possible such things as vacuum deposition or coating of many substances with a metal that otherwise would be prohibitively expensive. For example, optical lenses in cameras and field glasses receive a coating of magnesium flouride of only a few molecules thick to prevent glare and to improve the transmission of light from the air into the glass lense. By far the most common type of vacuum coating is the process of vacuum metalizing typical in the manufacture of costume jewelry, toys, electronic devices, etc., where a metallic sheen or surface is desired on plastic or other metal surfaces.

The forces for the most part arise from tiny electric dipoles (electric charges) formed in any asymmetrical molecule which attract each other not unlike little bar magnets. The other groups of forces in this category result from dispersion effects and by the hydrogen bridge. The latter provides attraction between water molecules and is responsible for its high boiling point. This force is found in the common household cleaner called ammonia (NH_3).

IV. Chemical Properties

A. Chemical energy

Every chemical reaction involves a change in energy. While the root form "thermic" indicates heat, today the term refers to all forms of energy, whether heat, light, electrical, etc.

1. Exothermic

Exothermic energy is released to the adjacent surroundings. For example, the chemical union of the molecules that compose gasoline and oxygen in the cylinders of cars generates so much heat that we are forced to have a large cooling system to carry the heat out to the radiator where it can be transferred to the air.

2. Endothermic

Endothermic energy is absorbed from the adjacent surroundings. Nitrogen will combine with oxygen to form the compound nitric oxide only if energy is supplied. Here we have a chemical reaction which results when the electrons are raised from their lower level of potential energy to high levels. The energy necessary for such a change must be supplied in the form of heat, electrical energy, or some other kind of energy.

B. Factors which influence speeds of reaction

Many substances combine with oxygen so slowly that years are required to complete the chemical reaction. In such cases, there is little or no light emitted and the total heat given off will be the same as if the combustion had taken place within a few minutes. Wood is a typical example of slow oxidation. When the heat evolves slowly, it can be radiated to the surroundings unless circumstances are present to prevent it, in which case the temperature will rise gradually. As oxidation rates increase rapidly with temperature, the kindling points of many combustible materials may be reached quite readily resulting in spontaneous combustion. Oil and linseed oil soaked rags present particular danger of this type of fire when piled one on top of the other. Gasoline and oxygen mixed and ignited in the proper ratios liberate heat so rapidly that we describe it as an explosion. In the car engine, this is defined as detonation because the fuel did not have a chance to burn slow enough. Often, the resins will ignite after the catalyst starts the reaction and generates too much heat and a nearly full container ignites itself.

1. Temperature of reactants

Reactions at low temperatures usually proceed very slowly as the thermal vibration is lower thus not hastening the exchange of electrons. But as thermal vibration of the atomic structure increases with temperature many reactions often become violent. A rise of ten degrees centigrade in temperature will double approximately the speed of reaction for many substances.

2. Concentration of reactants

If the reactants are diluted with something which is inert under the conditions of the process, the inactive parts slow the reaction. Thus, the amount of heat available for welding with gas and compressed air is below that required for working with iron, since 80% of the air is nitrogen and other gases. By increasing the concentration of oxygen from 20% to 100%, larger amounts of heat are liberated in the combustion and sufficient heat is available to melt most metals.

3. Nature of Reactants

The influence of the activity of various substances on the speed of reaction is quite apparent. The general activity of the metals in the middle of the periodic table varies greatly, but is always less than that of the alkali and alkaline earth metals. For example, aluminum and zinc are quite active, and iron moderately so, whereas silver and gold are inactive to the point of semi-inertness. There are other factors which determine the chemical activity. Often a film or coating forms on the surface of a metal to alter its reaction. Aluminum and magnesium react quickly when exposed to air, but a molecularly thin, closed packed film of oxide that forms protects the underlying metal. This oxide is an excellent nonconductor of electrons (an insulator) which prevents further oxidation. This principle is used to make the very large electrolytic capacitors which store electricity in electronic equipment, wherein aluminum-oxide is formed on one plate by electricity. On the other hand, the less active iron corrodes more rapidly because corroding chemicals easily pass through its porous and flaky iron-oxide, continuing the chemical reaction. The coating principle is used to manufacture our durable galvanized iron. Iron is protected from corrosion by a more active metal, zinc.

Zinc reacts readily with moisture, oxygen, and carbon dioxide and forms a tough film of zinc carbonate ($AnCO_2$) which resists further galvanic (producing electric current) attack.

4. State of subdivision (particle size)

If two substances are to react, it is evident that they must be in contact, and the more intimate the contact the more rapid the reaction may become. Fuel must be completely vaporized in the engine to achieve full combustion of the fuel/air mixture. When a piece of charcoal is burned in air the reaction proceeds slowly because the oxygen is in contact only on the surface. However, when it is pulverized and blown into the air, the air, the exposed surface area is increased many thousand times. If it is ignited, the reaction is so rapid that it may become an explosion. A mixture of powdered charcoal mixed with liquid oxygen in a cylinder becomes a powerful explosive for mining purposes. Many grain elevators have been destroyed by quantities of dust exploding during the processing of various grains, such as wheat and oats. A spark of any kind is all that is necessary to start the oxidation process.

5. Catalysts

A catalyst is a substance which alters the speed of chemical reaction without itself undergoing a permanent chemical change. It is thought to influence the change in one of two ways: (1) by the formation of intermediate compounds, or (2) by adsorption. The petroleum industry uses platinum in the cracking of crude oil to produce various grades of products. One oil company actually advertises "platformate" as an additive to its premium gasoline. In reality, the trade name comes from the use of a catalyst in "platinum forming" of different fuels.

C. Composition

The elements are present in compounds in definite ratios by weight. There are many methods for determining the percentage by weight of the different elements. These methods vary, depending upon the nature of the compound and the elments in it.

D. Chemical properties

If the physical properties of a substance do not serve to identify it, we may then study its ability to enter into certain chemical changes. Wood burns in air, producing gases and ash; fruit juice ferments producing vinegar; calcium carbide combines with water producing the acetylene gas.

E. Oxidation and reduction (corrosion, rusting)

Reactions involving a transfer of electrons from one atom or ion to another are known as oxidation-reducing reactions. The substance which loses electrons is "oxidized" and the one which gains electrons is said to be reduced. The term "oxidation" is somewhat misleading, for many cases of oxidation do not involve oxygen. While oxygen is a good electron attracter, it is not the only one so the word "oxidizing" has taken on a broadened meaning. While electrons can be transferred from one atom to another, they can never be created or destroyed, so the total number of electrons in the system must be the same after the reaction has taken place. When oxidation occurs in materials and it is undesired, it is known as corrosion.

1. Basic mechanisms of corrosion

Corrosion is the chemical process of deterioration of a metal by the environment which converts it into an oxide, salt, or some other compound. There are many types of corrosive media, e.g., air, acids, soil constituents, bases, salts, solutions, and various industrial atmospheres. Simply stated, the environment creates a chemical reaction which oxidizes and leaves the desirable metal incapable of performing its designed function. Iron is constantly being attached and changed to rust which is useless as a solid material. Typical reaction by which corrosion is accomplished are (1) combinations of metals with non-metals in the absence of water (2) combinations of metals with oxygen assisted by the presence of water, (3) displacement of hydrogen from acids, (4) displacement of hydrogen from electrolytic solutions, and (5) displacement of ions of a metal already in solution undergoing attack. The two basic mechanisms of attach are:

a. Direct chemical attack

This form includes all kinds of corrosion in which there is no appreciable flow of current through the metal for perceptible distances. Of course, there is an exchange of electrons between the substances involved in the formation of oxides and other compounds. A distinct characteristic of this type of corrosion is that it tends to be a coating, a smooth scale or resemble a film on the surface. High temperatures are generally a very important aspect of this type of oxidation as the energy levels of the valence electrons must be high to start and sustain the reaction. An excellent example is the oxidation of iron which creates thick sheets of iron-oxide during hot working processes to form or join sections together. High temperature corrosion involves oxidation or reaction with the products of combustion in engines and can be reduced with chromium alloys. A film of chromium-oxide (Cr_2O_3) forms on the steel and protects the latter.

Metals protected by the formation of passive layers lose their stability if the film is destroyed by erosion. This often happens to a brass water propeller when cavitation occurs at higher speeds. Vapor bubbles form and collapse on the surface which results in a pounding action, destroying the protective film, allowing further chemical reaction to occur and reoccur.

Small molecules and ions will dissolve most readily in a solvent. An example of the latter is table salt (NaCl) which dissolves as sodium and chloride ions in the water. When the solute is structurally similar to the solvent, the solubility is increased greatly. Here, we must avoid bringing polyethylene into hydrocarbon solutions as it is quite soluble due to their similar structures. Quite often, though, corrosion can be hastened by the presence of two solutes. An example of this eroding process is the resistance of calcium carbonate (limestone) in subterranean caves to oxidation by water until carbon dioxide forms carbonic acid in the water. The chemical reaction in every instance of solutions is increased by temperature because diffusion (a function of the amount of heat due to thermal vibration) increases the rate of electron transfer.

b. Electrochemical attack

This type of corrosion becomes possible with the establishment of anode and cathode areas on the metal in an electrolytic solution, often called galvanic cells. Essentially, it is the formation of a battery with a positive and negative terminal using conditions which are always present in most environments. In fact, one can actually consider it a complete electrical circuit with a power source, but performing a service we do not want--the oxidation of metals.

In the electrolytic corrodant (i.e. salt water) electricity flows by a movement of ions, and to complete the electric circuit, electrons flow through the metallic structure. In the case of metals (iron) the attack is localized rather than uniform as in direct chemical attack. It is most noticeable by the deep holes or pitting of the surface with unequal deposits of scales (rust).

The automobile water cooling system with its block of more active metal, iron, and less active metal, copper radiator, provides a perfect system for the destruction of the iron parts when ions leave the iron to become iron-oxide (rust) and plug up the cooling system so the engine will boil its water in just normal driving. Of course, rust inhibitors can be added to the water and become ions themselves to be attracted to the iron and "plate" it to stop the oxidation. The positive ions in solution will then be attracted to the iron (which tends to become negative and serve as the anode). Thus inhibitors set up a stable condition through this plating action and as one manufacturer sells his antifreeze, he advertizes that his product "has a magnetic film to protect your engine's vital parts." We can reverse this destructive process by supplying electrons from electric energy and save millions of dollars in the storing of reserve ships or pipelines running underground. By selecting the proper materials and reversing this process, we have the technology of electroplating used to prevent corrosion of automobile bumpers by a relatively inert coating of chromium.

A listing of metals which are more active in releasing their electrons in ionic solutions is called the activity series. The list is developed using hydrogen as the reference because it is reactive with most metals. This list has several names as electochemical series, displacement series, electrochemical series, and electromotive series. It is arranged so that any element in the series will displace any of the other metals below it in an electrolytic (ionic) solution of the latter metal. The sequence is in the order of decreasing ability to lose electrons. The anodic metals (those which sacrifice themselves [more active] are at the top of the list with the metals that form a cathode below.)

V. Classes of compounds

A. Covalent lattices

In the covalent lattice, the lattice points are occupied by atoms which share electrons with their neighbors. These covalent bonds extend in fixed directions. The strength of the covalent bonds and their interlocking character are responsible for the great hardness of the diamond. Since the bonds must be broken to melt the crystal, the temperature must be raised to 3500° C. Graphite is another form of carbon but it has different properties due to the arrangement of the carbon atoms. Each carbon atom is bonded to three others in the same place, forming a sheetlike structure. The sheets are weakly bound together allowing them to slide over each other easily. This is the reason for the softness of graphite and its greasy feel. However, the bonding within the individual sheets is strong so it has about the same melting point as the diamond.

B. Ionic lattices

In the ionic lattice, positive and negative ions occupy the lattice points. It is the electrostatic attraction between these oppositely charged atoms that holds them together. These positive and negative ions are arranged alternately in the three cardinal directions of space. One cannot pair up these charges, since each ion is surrounded by six others of the opposite charge, one in front and one behind, one above and one below, and one on each side. The whole crystal acts like one gigantic molecule. These attractions are large, so ionic crystals have moderately high melting points. To melt the crystal the attractions of these ions for one another must be overcome.

C. Metallic crystals

Ions of metals occupy the lattice points. The valence electrons are shared communally by all of the metallic atoms. Each atom contributes its valence electrons to an "electron cloud" that belongs to the whole crystal. In general the melting points depend upon the size of the atom and upon the number of valence electrons.

D. Molecular lattices

In the molecular lattice the lattice points are occupied by molecules. The forces within the atom-to-atom bonds are covalent and are much stronger than the forces between the molecules. The bonds may be polar or nonpolar.

1. Polar type

This type consists of polar molecules in which the positive and negative charges are not symmetrically distributed. There is a net "+" charge on one end and one of negative on the other. A molecule of H_2O or HCl, in terms of this electrostatic charge distribution is a dipole. A crystal of either is simply a geometric array of these dipoles arranged alternately in three dimensions of space. The binding energy of the crystal arises from the mutual attractions of the dipoles. The greater the inequality of the sharing of the electron bond (the more highly polar) the higher the melting point. The melting point is a measure of the thermal energy required to separate the dipoles. They will be considerably lower than those of ionic crystals, for the attraction between two ions. The melting points will be still lower in crystals with covalent bonds because the bonds within the molecules of molecular crystals are not broken during melting, whereas in covalent crystals they are broken.

2. Nonpolar type

The bonding within the molecules is covalent as in the polar molecular lattice. The difference is that the individual molecules are nonpolar (no dipoles). The binding forces have their origin in the motion of the electrons. Since the electrons are in motion around the nucleus, their actual location at any instant is not symmetrical; they are symmetrical only on the average. Therefore, at any particular instant the molecule may be slightly polar--an instantaneous dipole exists. At the next instant the molecule may be completely nonpolar, and at the next, the instantaneous dipole is reversed. It is clear that the more electrons there are in the molecule and the farther they are from the nucleus (and less tightly bound) the greater the Van der Waals forces are. Since Van der Waals forces are weak at best, the melting points of nonpolar molecular crystals are low, and the weaker these forces, the lower the melting points.

E. Organic and Inorganic Compounds

Materials which contain carbon are classed as organic, while those which do not are called inorganic compounds. The organic materials which occur in nature are found mostly in plants and animals or derivates thereof such as coal, natural gas, petroleum, fats, proteins, and alcohols. Today, thousands of organic compounds are synthesized in chemical laboratories. These tend to be covalent, although many are electrovalent. The inorganic group include such materials as clay, sand, and other earthy materials like calcium carbonate, sodium chloride, etc.

F. Electrolytes

Molten compounds, or their solutions which contain ions and will conduct electricity are classed as electrolytes. Ordinary table salt, calcium chloride, is a non-conductor until it is molten or dissolved in water. Those that do not conduct are classed as non-electrolytes.

1. Acids

These are defined as substances which donate positive hydrogen ions ($H+^1$) in chemical reactions. In general, acids: (1) have a sour taste, (2) react with active metals to liberate hydrogen to the air, (3) cause color changes with the indicators, litmus and phenothalein, and (4) neutralize bases. Sulphuric acid is greatest and is a measure of the charge because the acid has the greater specific gravity--a floating bulb will rise higher in the acid. During discharge the acid decreases and becomes lead sulphate and water and the specific gravity drops. A dead cell of a battery will no longer react chemically to form sulphuric acid so must be replaced.

2. Bases

Those substances which accept a positive hydrogen ion in a chemical reaction are bases. Water solutions of bases contain two distinct sets of ions and furnish the hydroxide ion (OH^-). Bases have a bitter taste; reverse the color produced by acids on indicators; and neutralize acids. Sodium hydroxide is a strong base and when in water solutions, it exists entirely as positive ions of sodium and as a negative hydroxide (OH^-) If this is mixed with an acid, the hydrogen (+) ions will react with the hydroxide ion (-) to form water (H_2O). This is the fundamental reaction which occurs when acids and bases neutralize each other.

3. Salts

Salts are defined as ionic compounds containing a positive ion other than the positive hydrogen ion ($H+^1$), and a negative ion other than the hydroxide (OH^{-1}). Some examples are sodium chloride, calcium carbonate, sodium sulfate, and calcium chloride. These salts are electrovalent and exist in water solutions entirely as ions. When a solution of any strong acid is neutralized by any strong base, the negative ions present in the acid and the positive ions present in the base remain in the water solution. When the water is evaporated, a salt is obtained.

The sea contains sodium chloride that reacts quite readily with the iron ships, which if unprotected, would soon be reduced to iron oxide. Every once in a while some unwary motorist attempts to prevent the cooling system of his car from freezing in the winter by adding salt. While it will prevent the damage resulting from freezing, its hydroxide ion (negative) reacts with iron ions (positive) to form iron oxide and plug and ruin the cooling system. In the Eastern and Northern parts of the United States, calcium chloride is used to melt ice on the streets, and as expected, cars rust underneath quite badly. Cars driven upon the sea shore also suffer from such damage. All require frequent washing with fresh water and/or other methods to reduce the oxidation.

VI. States of Matter
  A. Gas
    1. Compressibility
    2. Effects of temperature
      a. Contraction
      b. Expansion
    3. Diffusion
    4. Liquefaction
    5. Pressure
    6. Van der Waals forces
  B. Liquids
    1. Compressibility
    2. Effects of temperature
      a. Contraction
      b. Expansion
    3. Diffusion
    4. Evaporization and solidification
      a. Vapor pressure
      b. Boiling
      c. Condensation
    5. Van der Waals forces
  C. Solids
    1. Compressibility
    2. Effects of temperature
      a. Contraction
      b. Expansion
    3. Diffusion
    4. Crystalline solids
      a. Types
        1) isomorphism
        2) polymorphous
        3) amorphous
    5. Van der Waals forces
    6. Sublimation

VII. Physical Properties

Physical changes are changes in the condition or state of a substance; they do not result in the formation of a new substance nor involve a change in composition. If we file a piece of iron into tiny iron filings, we observe a definite change, yet the particles still have the same characteristics of iron.

A. Extrinsic properties
   1. Size
   2. Shape
   3. Length
   4. Weight
   5. Temperature
B. Intrinsic properties
   1. Odor
   2. Taste
   3. Texture
   4. Color
   5. Transparency
   6. Melting point (fusion)
   7. Boiling point
   8. Density
   9. Viscosity
   10. Hardness
   11. Refractive index

VIII. Energy

Energy is something that enables us to create, to build, and to be comfortable. We pay monthly bills for energy of various types, i.e., electricity, natural or liquefied gas, gasoline, coal, etc. We harness the energy of the wind, falling water, and the atom. Energy, then, is the capacity to do our work. A measure of a country's technology is the amount of horsepower available per person. The more power, the more work that can be done by each individual.

We obtain most of the energy we use, with the exception of electricity, in the form of chemical energy which we call fossil fuels. They are given this name because they were created by the energy radiated to Earth by the Sun many thousands of years ago and converted into plant and animal matter. Thus, various elements were combined into molecules under the forces of nature, raising the energy levels of the atomic particles and storing the energy as potential energy. It is through the process of oxidation which we call combustion that this potential energy is released as kinetic energy so that machines or devices of various kinds can convert it into other more usable forms. Unfortunately, our conversion machines--engines and furnaces--are very inefficient, wasting as much as 75% to 80% of the total energy stored in the fuel, and filling the atmosphere with unburned fuels and other derivatives to pollute the supply of oxygen which the human body needs for its oxidation process.

The basic forms of energy are: heat, light, chemical, mechanical, electrical and nuclear. Chemical fuels as the major supplier of energy for man will decline rapidly after the year 2000 because of the rate we are using our fossil sources. Science has found another major source in the form of nuclear energy which is expected to become our major source of energy for the next 1,700 years. By using various devices and machines we can convert any form of energy to another in order to perform any specific task. Chemical energy is converted into heat energy by furnaces and engines. Engines convert heat into mechanical energy to propel vehicles. Mechanical energy can be converted into electricity by generators. Electricity can be converted to light easily by heating metals or changed back to mechanical energy by motors. Secondary batteries (wet cells) store electricity by a reversible chemical reaction.

The transformation of potential energy into kinetic energy often occurs with the generation of heat. Pulling a nail from a piece of wood will raise its temperature. The brakes of an automobile will get hot and fail when used extensively on a long downhill grade, or a cutting tool on a lathe turns blue as it removes steel from the work piece. In all of these cases, and others too, kinetic energy disappears and heat appears as the result of friction. In the case of the automobile it would be more desirable to stop the car by storing the energy in a battery, but unfortunately, it is not economical to do this so we convert it to heat with brakes and then transfer it to the atmosphere. If the brakes cannot transfer the heat fast enough, we design larger cooling surfaces or make them larger. In reality then, man is primarily concerned in the transformation of energy from one form into a more desirable form: Heat is more preferable than reshaping the front end of a car in a collision.

1. Heat energy

Heat energy is transferred from one body to another by three mechanisms: (1) conduction as in the case of brakes by the metal drums to the air, (2) convection by heated air rising from a hot surface and moving to another location, and (3) radiation through electromagnetic waves as the earth receives energy from the sun. The natural transfer of energy is always from the higher level to the lower level--heat always flows from the hotter to the cooler material in the same way that water always flows down hill and not up.

The total heat content of a gas, liquid, or a solid is the sum of the energies of the molecular motions. As the amount of heat in a substance is reduced the vibrations of the molecules and atoms are reduced. Before reaching absolute zero, all gases become liquids or solids, which in turn lose random kinetic energy. There is no friction involved between molecules; they are elastic and do not lose energy as a bouncing ball does and finally come to rest. Heat is molecular motion. Temperature is merely a measure of the intensity of the heat. The absolute scale of temperature (kelvin) is based with its zero at the point when all random molecular motion of molecules has ceased. The scales of Centigrade and Fahrenheit are arbitrary ones.

When a gram of water is boiled at 212° F., the temperature will not rise until 540 calories of heat are added to make the water turn to steam, which will still be at 212°. This extra amount of heat energy, called the heat of vaporization, is required to break the chemical bonds called the Van der Waals forces. These forces determine whether the water will be a liquid or a gas. When cooled, this extra amount of energy is returned as the heat of condensation. This principle is at work in the development of the towering cumulus clouds. As the moisture in the air condenses into clouds, heat is released to warm the surrounding air which will continue to rise. As the air rises further it cools more, continuing to release more energy and rising even higher until the air has insufficient vapor to condense. Similarly, the amount of heat given up when a substance solidifies is called the heat of solidification, such as water to ice. Upon return to a liquid, the amount of heat that must be added just to change the chemical bonds is called heat of fusion.

2. Electromagnetic energy (radiant)

Hot bodies radiate heat and sometimes light, although their difference is only one of wave length and frequency. Bringing a piece of iron up to hot working temperatures will cause it to emit lots of heat and very little light. However, as more and more heat is added, the metal glows brighter until it reaches a "white heat". At this point the entire atomic structure is vibrating near the point of breaking apart into a liquid. The filaments in incandescent lights use this concept to generate energy to radiate. The mechanism for radiation occurs when the energy absorbed by the electrons raises their energy levels which become excited and unstable and drop back emitting a burst of electromagnetic radiation. The electrons will return to a lower discrete energy level, and in occupying it, bursts (quanta) of electromagnetic radiation are liberated. The frequency and its inversely related wavelength will be determined by the particular element and its energy levels, which in turn places it as radio waves, infrared, visible light, or ultraviolet.

3. Chemical energy

Quite often, the energy of gasoline, food, batteries, and explosives is referred to as potential energy. While true, it more appropriately is called chemical energy. In order to be useful as energy, it must be converted or transformed by some process. For example, when gasoline or wood is burned, or the food we eat is burned in the cells, chemical energy is converted to heat or light energy, or both by the process of oxidation wherein the electrons drop back to a lower level of energy. The energy we obtain by burning any fuel, (e.g., gasoline, wood, or coal) comes indirectly from the sun by radiation.

4. Nuclear energy

The discovery that a neutron can cause the nucleus of an atom to split apart and in turn release more neutrons to repeat the action made possible the development of a new source of energy through a chain reaction. When this occurs the binding energy of the nucleus is released mostly in the form of heat. A sudden release of energy is an explosion which is used for the atomic bombs. The slow release of energy by heating water and generating steam to drive large turbines, permit the development of large amounts of electric energy not unlike the older steam plants powered by fuel oil, coal, or natural gas.

5. Mechanical energy

Mechanical energy is used to do work (1) against friction, (2) against gravity, (3) against the inertia of a body, or (4) against any combination of the first three. In order to make a car move, energy must cause the car to overcome inertia, (the desire to remain at rest) then overcome the friction of the moving parts and tires on the ground, and finally, climb over hills as gravity pulls the car down. The energy to do this is mechanical energy derived from some basic source of energy such as fossil fuels.

6. Electric energy

There are three mechanisms by which electricity is conducted in solids. These are: (a) ion movement, (b) electron movement, and (c) movement of electron vacancies (holes). The possibilities for conduction of electricity by ions in most solids is extremely limited since ions are strongly bonded to their nearest neighbors. However, as the temperature rises, the ions become more mobile and free to change places with their neighbors, as in the case of molten ionic solutions. The massive size and weight of the ion, even in a liquid, will cause its movement to be sluggish with very low conductivity in comparison to the easy movement of the electron which weighs only 1/1836th that of the proton. The loss or gain of an electron in the atomic structure during the creation of an ion has, for all practical purposes, no effect upon the total weight of the ion.

Valence electrons in metals are not held tightly by a specific ion (atom). Thus, their energy levels are in the conduction band which permit them to diffuse through the crystal structure. If an electric field is superimposed upon a conducting type of material (copper, aluminum, and even steel) the electrons will drift quite readily according to the law of charges. The negatively charged electrons will be repelled by the end of the conductor connected to the negative terminal of the power source, while the positive side will attract the electrons. The flow of electrons, called electricity, will impart their energy to the conductor when they collide or strike the atomic structure. This causes heat and a temperature rise, increasing thermal vibration at the same time increasing the resistance to flow much as a person would face trying to walk across a crowded dance floor. By increasing the music tempo and the dancers moving in larger steps, any attempt to go directly across would meet even greater (larger) resistance. This is known as a positive temperature coefficient.

If a resistance device (resistor) with greater opposition to the flow of electrons is inserted in the conductor, practically all of the effects of heat due to the electron flow can occur in it. This is why we use large conductors with low resistance for battery cables and power cords. Electric iron cords often get hot in use because the high current (flow of electrons) creates enough heat to warm it. A flashlight is made possible by inserting a tiny filament of tungsten steel (high resistance) in a conductor with dry cells (chemical oxidation of zinc in an electrolyte.) The heat generated by the flow of electrons in it reaches the point of incandescence, where the electrons are raised to very high energy levels and their return to a lower level emits the electromagnetic radiation in frequencies of visible light and infrared. The heat of the filament also causes it to react with the oxygen of the air and quickly oxidizes and the filament burns out. Of course, Mr. Thomas Edison found this could be prevented by removing the oxygen inside a glass envelope. While a vacuum is most common, some manufacturers add argon or some other inert gas after all oxygen is pumped out.

Let us turn to the third mechanism that makes the flow of electricity possible and we commonly use it in semiconductor material for transistors. In these covalently bonded solids, the only means by which conduction can occur is by electron movement or movement of electron vacancies called holes. The hole can be considered a positive charge because it would be neutral if the electron that belonged there was there. The reason it isn't represents one of the greatest developments of science and technology. It might even be called a trick because an imposter element is sneaked into the crystal structure to make it all possible.

Since the hole is considered a positive site and it is typical of this mechanism we call the material which permits it P-type. This is easily recognized in the names PNP and NPN type of transistors. The production of semi-conductors requires high-purity germanium or silicon crystals in which an impurity element can be put into the lattice structure. To create the P-type material with electron vacancies (holes), the impurity atom is selected which has only three valence electrons instead of the four as in the base material of silicon. When the electron-pair bonds (covalent) are formed around each atom, there will be only three such bonds wherever the imposter is located with one electron unpaired. Now recall the stable octet. The P-type material will grab the first wandering electron and complete the electron-pair. Of course, we are now short one electron which must be supplied by the power source which will also be looking for another one since it has a deficiency of one.

The actual flow of hole current is made possible because the electrons must jump through the vacant sites. So if the electrons are flowing, say to the left, the holes have an apparent movement to the right. This concept of current flow is in the same direction as the so-called conventional (positive) current flow, but remember, it can occur only in the semi-conductor and not in metallic conductors.

The N-type material utilizes the electron flow mechanism by simply using impurity elements that have five valence electrons to the four of the pure elements of silicon or germanium. With four electron-pair bonds completed around each atom there is an extra electron free to drift about very much like those of the metallic bonded metals. Since there are excess electrons we say it is negative N-type

Energy must be supplied by some source which can drive the electrons into conduction. This force is called electromotive force because it can cause electrons to move in a complete circuit of conductors. Since magnetism will affect an electron, all of our generators use this principle. By using dissimilar metals and supplying heat we can cause electrons to leave the more active metal and flow providing us with such things as thermocouples to measure heat. Chemical energy is developed by different metals and non-metals in batteries. Friction or static electricity occurs by mechanically transferring electrons from one substance to an insulator. The best example of all is lightning created in clouds through friction over the earth or inter-cloud. Of course, walking across a wool rug can create a shocking experience, as well, when the conditions are just right. Another source of energy is the piezoelectric effect where a mechanical force on certain crystals can cause electrons to move through a crystal structure and perform useful work in a circuit. These are quite common in pick-up arms on record players and microphones.

IX. Summary

The student faces a perplexing problem in integrating all of the complex knowledge available on industrial materials. This is especially so when it is recognized that he needs to master the real source, the atomic structure, in order to select the right material to perform a task. For example, how does one explain why a coat of paint failed to perform satisfactorily when the forces of attraction are not known, that a welded joint failed because conditions for oxidation were ideal to cause an early failure of the structural members, or that his car would not start because high resistance developed in the electric wires due to corrosion. While all of these instances are rather removed from each other, yet all are a part of the automobile which he drives. There are common threads woven throughout each.

Basically the arrangement of the electrons in the valence band of the atom determine the characteristics of elements and molecules. The manner in which elements combine depends mainly upon the number of electrons in the outside ring, combining by a transfer of electrons to form ions or by sharing of pairs of electrons to form molecules. When atoms combine with one another there is a chemical reaction where heat is liberated or it is added to cause it to occur. Compounds are made by bringing together two or more different elements, held together by either electrovalent or covalent bonds. In a very general sense, a chemical reaction occurs when, and only when, a valence bond is made or broken. When a substance changes chemically, there are three indications of this change. These are changes in properties, in composition, and in chemical energy of the substances involved. Once a material has been created, then these characteristics become very important in their application if the material will survive in its environment. Failure to do so will result in oxidation, failure when any heat or strength characteristics are exceeded, etc. In other words, the creation or destruction of a substance occur when chemical bonds are made or broken, when certain materials have an effect upon each other, too much or not enough heat or stress is applied, or in the presence of oxidants. While a student should conduct a quantitative and a qualitative analysis of matter, it is not necessary that he have such a complete storehouse of knowledge. A basic understanding of how materials react would seem to be quite sufficient for most purposes. In our present technology, materials can no longer be used indiscriminately, for many with all their additives, react unfavorably in contact with each other or in different environments.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

This should be evaluated by normal testing techniques and direct observation during the conduct of experiments.

UNIT EVALUATION:

This will require considerable time. Since the presentation of this unit involves the development of the more basic concepts of the structure of matter, only observation and analysis through testing over a period of time will provide an adequate evaluation of the effectiveness of this unit. The majority of the students should, with assistance of the teacher, begin to view materials in terms of the basic concepts presented herein. Once students begin to integrate all they know of materials and energy in the various forms, they should become more efficient in problem solving, in conducting experiments, and project construction through the proper application of materials.

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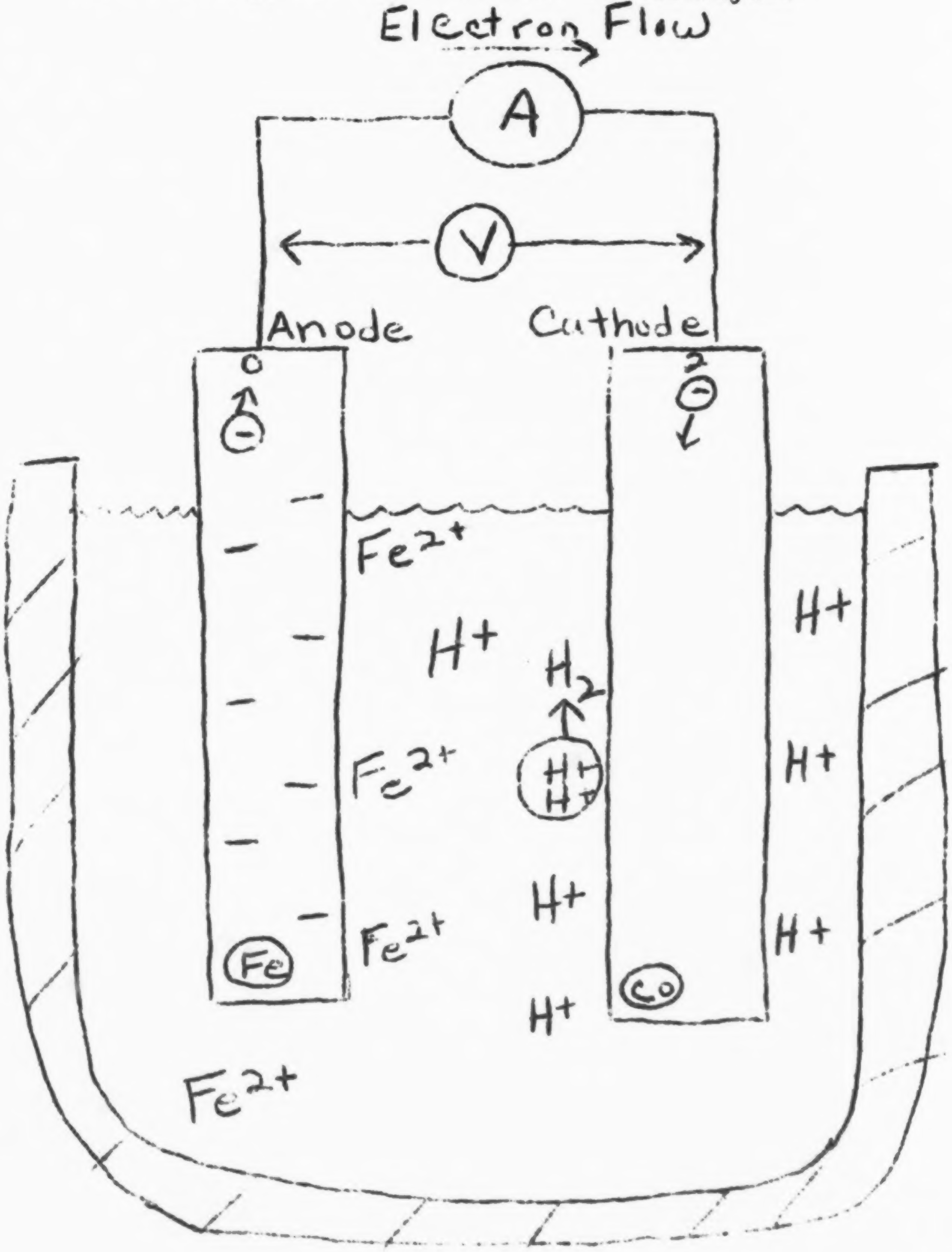
1. Booth, V. H., Physical Science, A Study of Matter and Energy, New York: MacMillan Co., 1962.
2. Hopkins, B. Smith, and John C. Bailar, General Chemistry for Colleges, Boston: D.C. Heath Co., 1957.
3. Keyser, Carl A., Materials Science In Engineering, Columbus, Ohio: Charles E. Merrill Pub. Co., 1968.
4. Van Vlack, Lawrence H., Elements of Materials Science, Palo Alto: Addison-Wesley Pub., Inc., 1964.
5. Wood, Jesse H., and C. W. Kerman, General College Chemistry, New York: Harper and Brothers Publishers, 1957.

DEMONSTRATIONS AND EXPERIMENTS

A. Magnetic induction of electricity. To demonstrate this phenomenon, wrap an enameled copper wire around one end of an open cardboard box (approximately 2" x 2"). Put at least 200 turns (wraps) of wire and tape it down. Connect the ends of the wire to a vacuum tube voltmeter (11-megohm input) and set the meter on DC+ (or DC-) and center the needle on the meter by using the zero adjust. Obtain a very strong permanent horse-shoe magnet (those used on magnetrons work the best) to force the electrons to move in the conductor. Move one side of the coil in and out between the poles and observe that a voltage develops, with the voltage rising or falling according to whether the coil is going in or out of the magnetic field. This is actually alternating current because the current and the polarity of the voltage is reversed when the coil is removed.

B. Electron flow due to dissimilar metals in an electrolyte.
Provide the following experiment according to the diagram for each two students to measure and record current and voltage. Use strips of copper and iron about 1/2" wide. Regular chemistry beakers or ordinary glasses may be used to hold the tap water. In some areas of the country, soft water may slow the reaction down, so add a few grains of table salt. After completing the measurements, students may connect the strips with copper wire and set the beaker up to observe the corrosion that develops on the iron in the form of rust. Replace the copper with a metal more active than iron, like zinc; will prevent the iron from rusting, but the zinc will be destroyed.



C. The corrosion of iron due to oxygen deficiency. Place a piece of new, clean sheet iron (2" square) in a beaker (or glass) of tap water. Put a small pile of sand on the iron sheet. After several days, the area under the sand will show evidence of corrosion because oxygen depletion makes that area anodic, or more active, than the remainder of the iron and electrons will flow from there to the exposed areas which are cathodic. In principle, it is the same as experiment C above, which can be used to create electricity in the progress of oxidation. In this experiment it will not be possible.

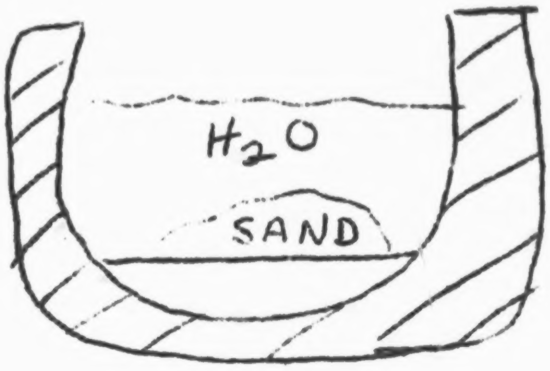


TABLE OF ELECTRON CONFIGURATIONS

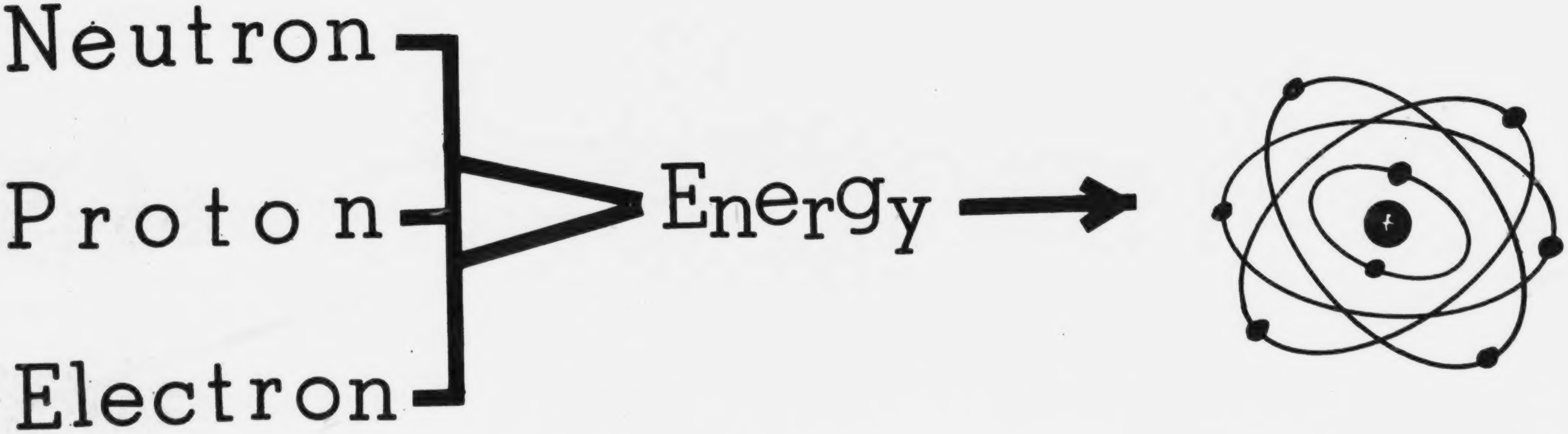
Name	Symbol	At. No.	Electron Population					
			K	L	M	N	O	P
HYDROGEN	H	1	1					
HELIUM	He	2	2					
LITHIUM	Li	3	2	1				
BERYLLIUM	Be	4	2	2				
BORON	B	5	2	3				
CARBON	C	6	2	4				
NITROGEN	N	7	2	5				
OXYGEN	O	8	2	6				
FLUORINE	F	9	2	7				
NEON	Ne	10	2	8				
SODIUM	Na	11	2	8	1			
MAGNESIUM	Mg	12	2	8	2			
ALUMINUM	Al	13	2	8	3			
SILICON	Si	14	2	8	4			
PHOSPHORUS	P	15	2	8	5			
SULFUR	S	16	2	8	6			
CHLORINE	Cl	17	2	8	7			
ARGON	A	181	2	8	8			
POTASSIUM	K	19	2	8	8	1		
CALCIUM	Ca	20	2	8	8	2		
SCANDIUM	Sc	21	2	8	9	2		
TITANIUM	Ti	22	2	8	10	2		
VANADIUM	V	23	2	8	11	2		
CHROMIUM	Cr	24	2	8	13	1		
MANGANESE	Mn	25	2	8	13	2		
IRON	Fe	26	2	8	14	2		
COBALT	Co	27	2	8	15	2		
NICKEL	Ni	28	2	8	16	2		
COPPER	Cu	29	2	8	18	1		
ZINC	Zn	30	2	8	18	2		
GALLIUM	Ga	31	2	8	18	3		
GERMANIUM	Ge	32	2	8	18	4		
ARSENIC	As	33	2	8	18	5		
SELENIUM	Se	34	2	8	18	6		
BROMINE	Br	35	2	8	18	7		
KEYPTON	Kr	36	2	8	18	8		
RUBIDIUM	Rb	373	2	8	18	8	1	
STRONTIUM	Sr	38	2	8	18	8	2	
YTTRIUM	Y	39	2	8	18	9	2	
SIRCONIUM	Zr	40	2	8	18	10	2	
NIOBIUM	Nb	41	2	8	18	12	1	
MOLYBDENUM	Mo	42	2	8	18	13	1	

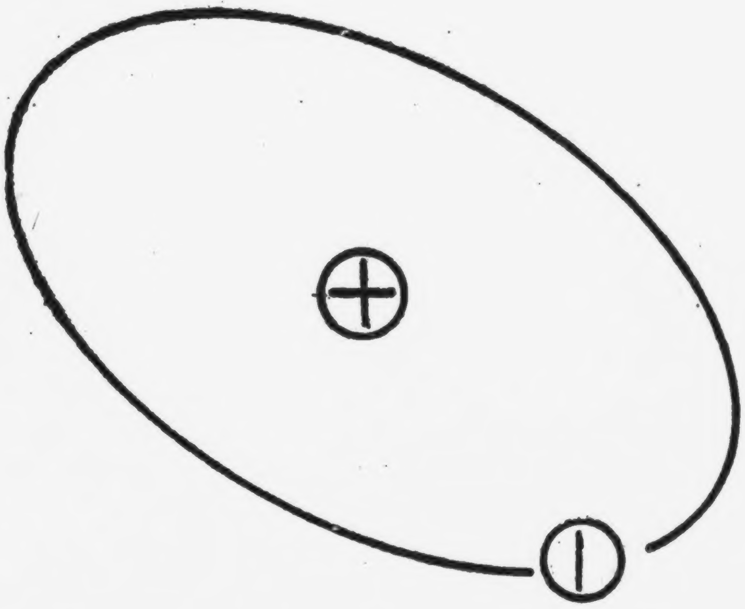
TABLE OF ELECTRON CONFIGURATIONS (cont)

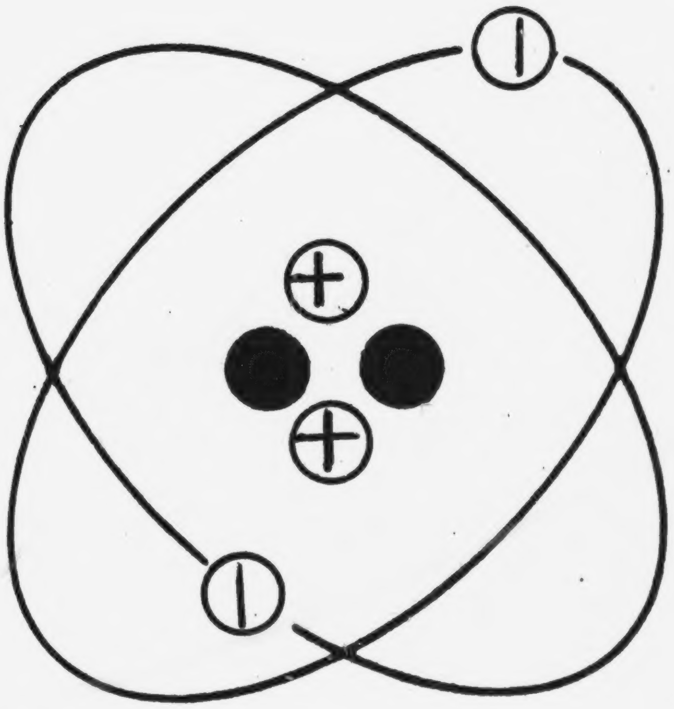
Name	Symbol	At. No.	Electron Populations					
			K	L	M	N	O	P
TECHNETIUM	Tc	43	2	8	18	13	2	
RUTHENIUM	Ru	44	2	8	18	15	1	
RHODIUM	Rh	45	2	8	18	16	1	
PALLADIUM	Pd	46	2	8	18	18		
SILVER	Ag	47	2	8	18	18	1	
CADMIUM	Cd	48	2	8	18	18	2	
INDIUM	In	49	2	8	18	18	3	
TIN	Sn	50	2	8	18	18	4	
ANTIMONY	Sb	51	2	8	18	18	5	
TELLURIUM	Te	52	2	8	18	18	6	
IODINE	I	53	2	8	18	18	7	
XENON	Xe	54	2	8	18	18	8	
CESIUM	Cs	55	2	8	18	18	8	1
BARIUM	Ba	56	2	8	18	18	8	2
LANTHANUM	La	57	2	8	18	18	9	2
CERIUM	Ce	58	2	8	18	19	9	2
PRASEODYMIUM	Pr	59	2	8	18	20	9	2
NEODYMIUM	Nd	60	2	8	18	22	9	2
PROMETHIUM	Pm	61	2	8	18	23	8	2
SAMARIUM	Sm	62	2	8	18	24	8	2
EUROPIUM	Eu	63	2	8	18	25	8	2
GADOLINIUM	Gd	64	2	8	18	25	9	2
TERBIUM	Tb	65	2	8	18	26	9	2
DYSPROSIUM	Dy	66	2	8	18	28	8	2
HOLMIUM	Ho	67	2	8	18	29	8	2
ERBIUM	Er	68	2	8	18	30	8	2
THULIUM	Tm	69	2	8	18	31	8	2
YTTERBIUM	Yb	70	2	8	18	32	8	2
LUTECTIUM	Lu	71	2	8	18	32	9	2
HAFNIUM	Hf	72	2	8	18	32	10	2
TANTALUM	Ta	73	2	8	18	32	11	2
WOLFRAM	W	74	2	8	18	32	12	2
RHENIUM	Re	75	2	8	18	32	13	2
OSMIUM	Os	76	2	8	18	32	14	2
IRIDIUM	Ir	77	2	8	18	32	17	
PLATINUM	Pt	78	2	8	18	32	17	1
GOLD	Au	797	2	8	18	32	18	1
MERCURY	Hg	80	2	8	18	32	18	2
TAHLLIUM	Tl	81	2	8	18	32	18	3
LEAD	Pb	82	2	8	18	32	18	4
BISMUTH	Bi	83	2	8	18	32	18	5
POLONIUM	Po	84	2	8	18	32	18	6
	At							

2

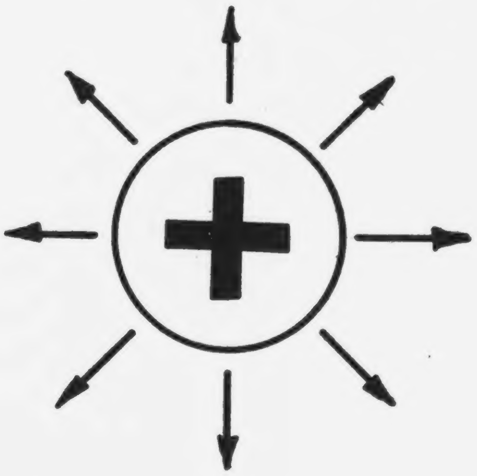
1


Neutron
Proton
Electron
Energy



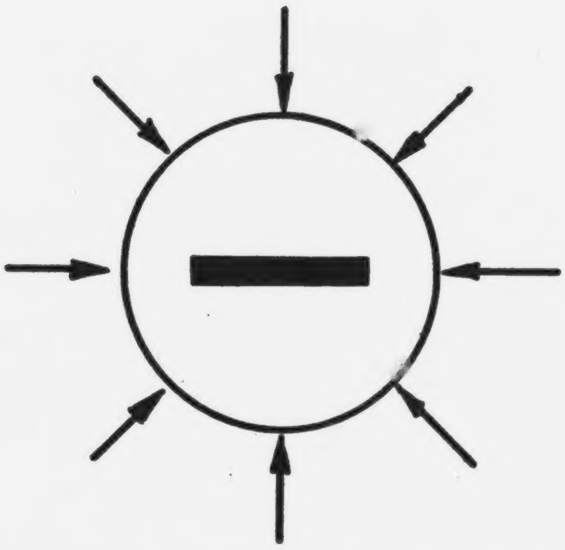


ELECTRIC CHARGES
(ELECTROSTATIC LINES OF FORCE)



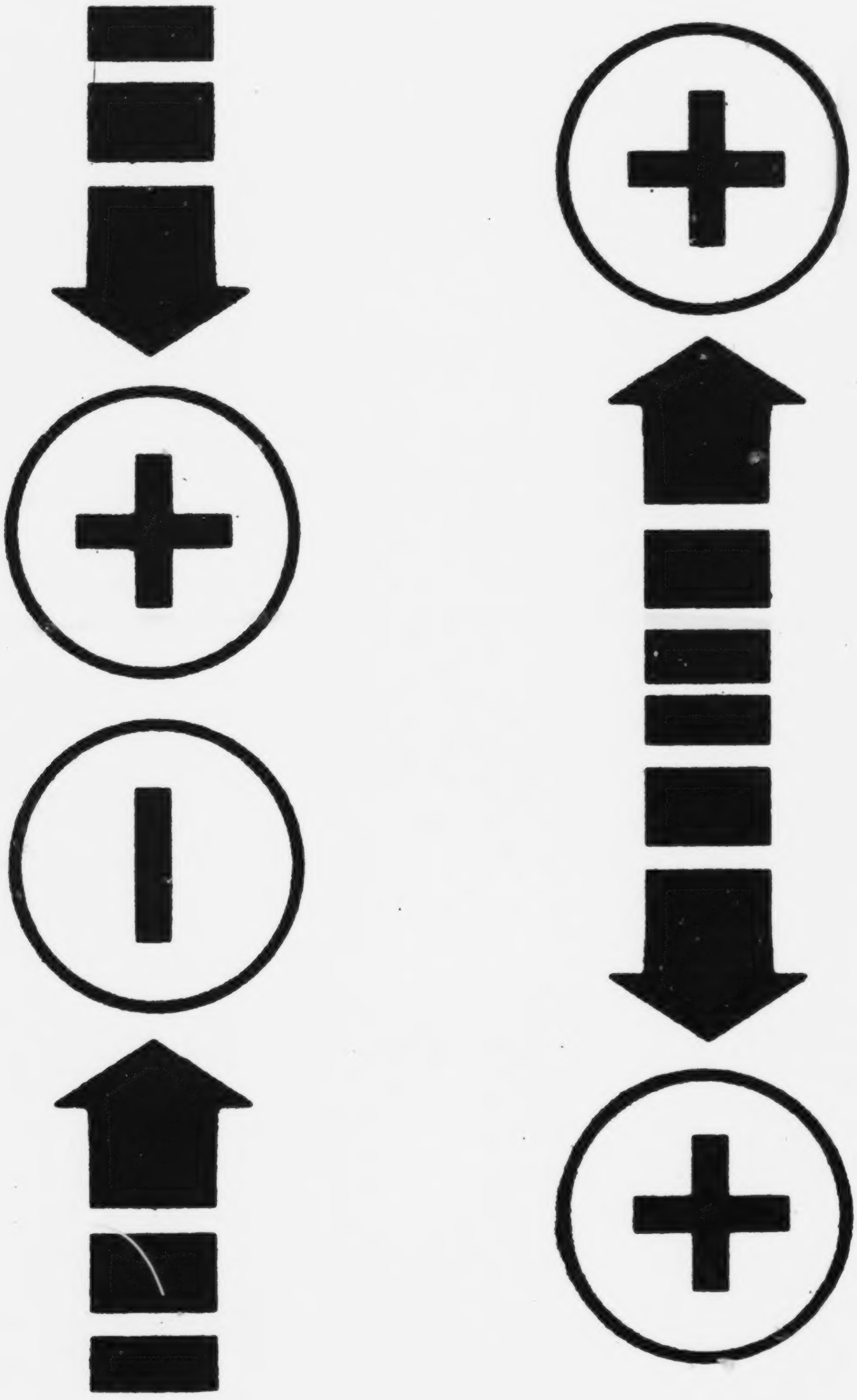
PROTON

NUCLEUS OF ATOM ALWAYS POSITIVE BECAUSE OF PROTONS. NEUTRONS HAVE NO CHARGE.



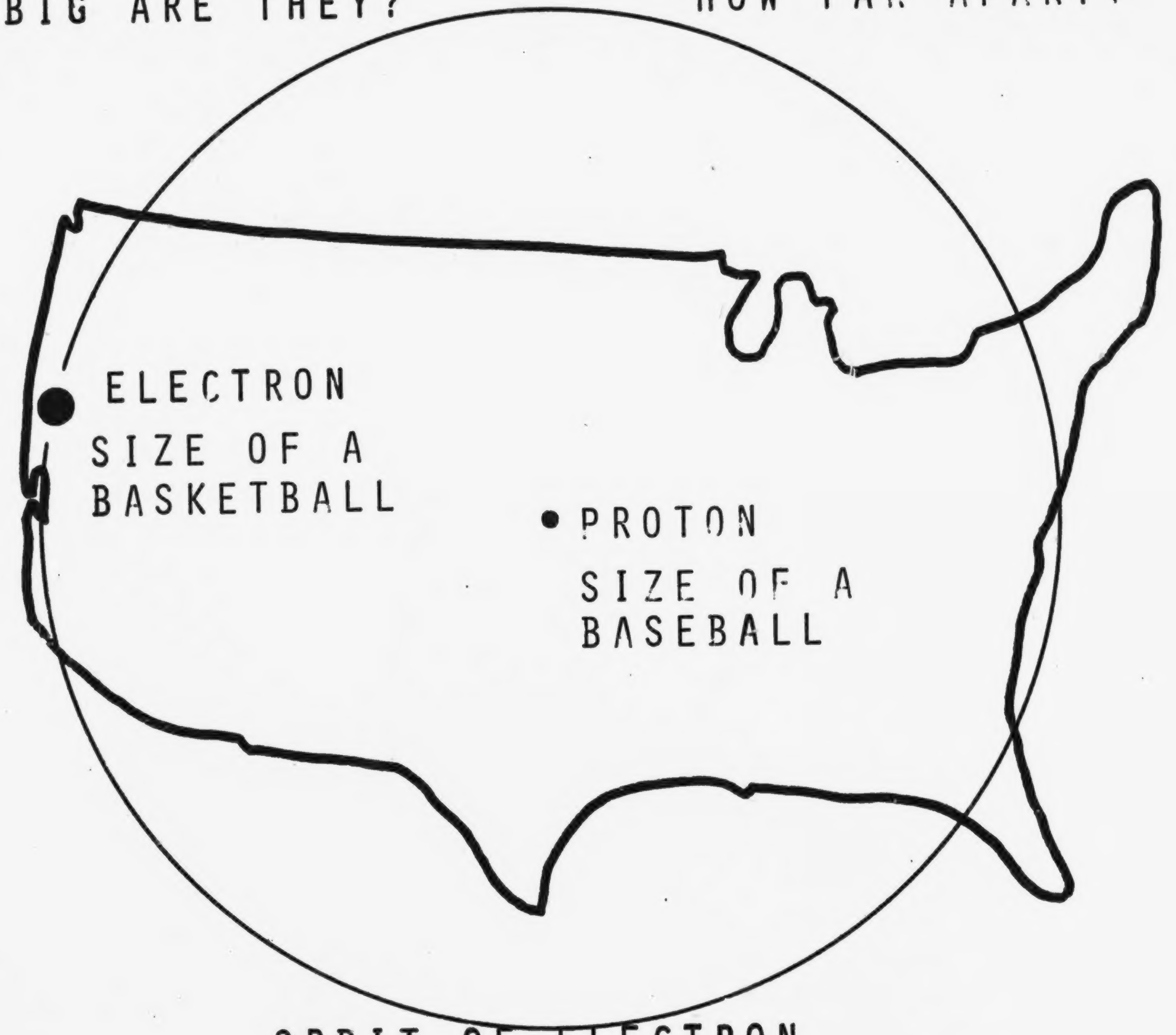
ELECTRON

LINES OF FORCE ASSUMED TO COME INTO THE ELECTRON.



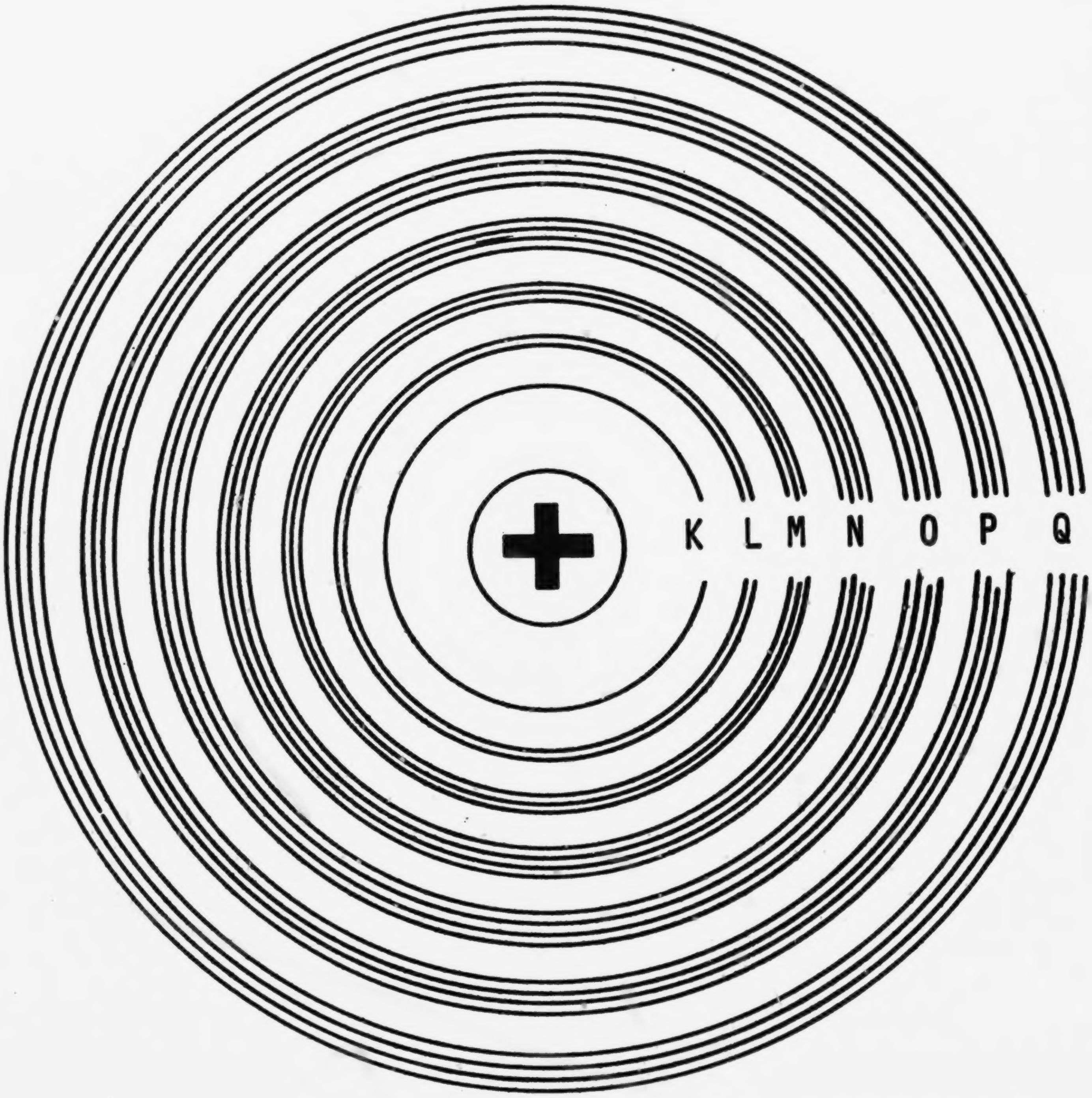
THE ELECTRON IS A NEGATIVELY CHARGED PARTICLE
A PROTON IS A POSITIVELY CHARGED PARTICLE

HOW BIG ARE THEY? HOW FAR APART?

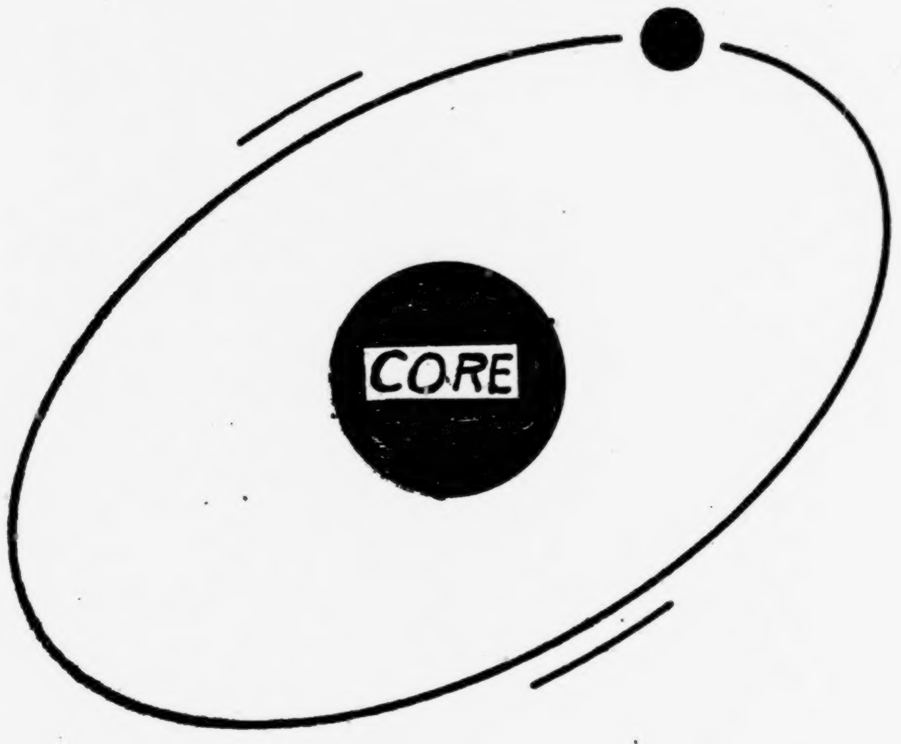

ELECTRON
SIZE OF A
BASKETBALL
PROTON
SIZE OF A
BASEBALL

ORBIT OF ELECTRON

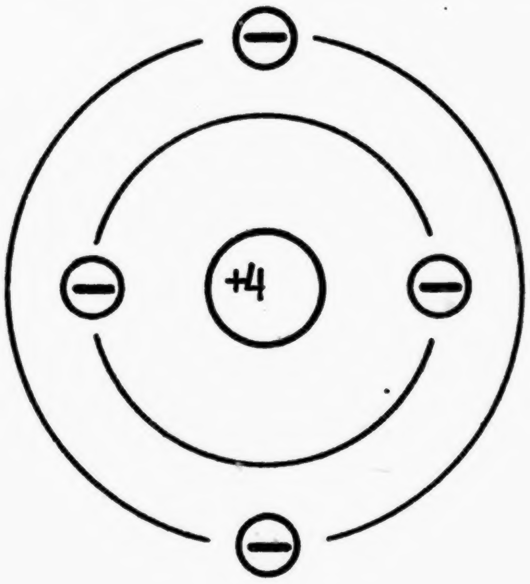
SHELLS
(ENERGY LEVELS)



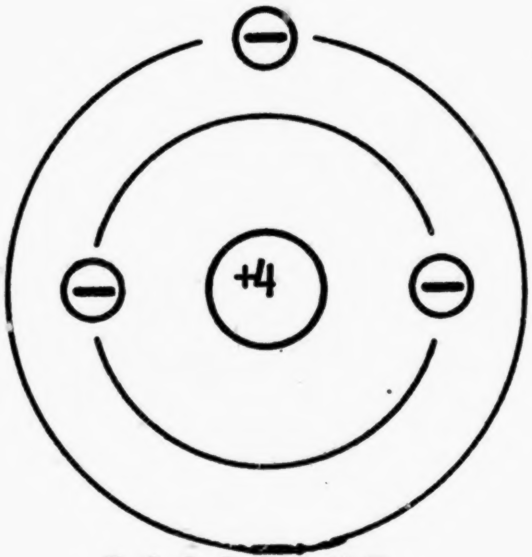
NOTE: ORBITALS ARE NOT ACTUALLY FLAT AS DEPICTED.


CORE

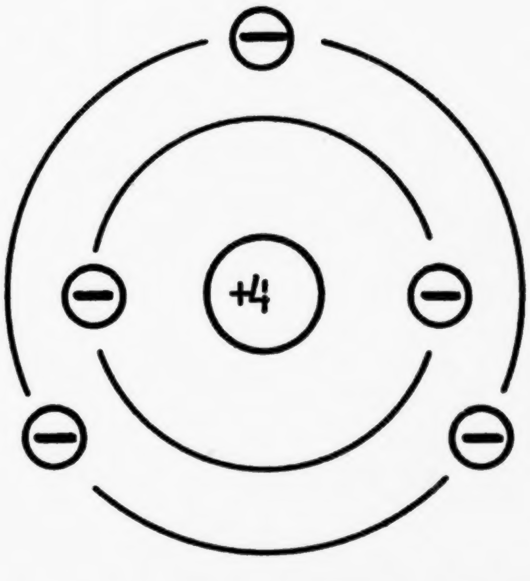
IONS (CHARGED PARTICLES)



A NEUTRAL ION OR BALANCED ATOM



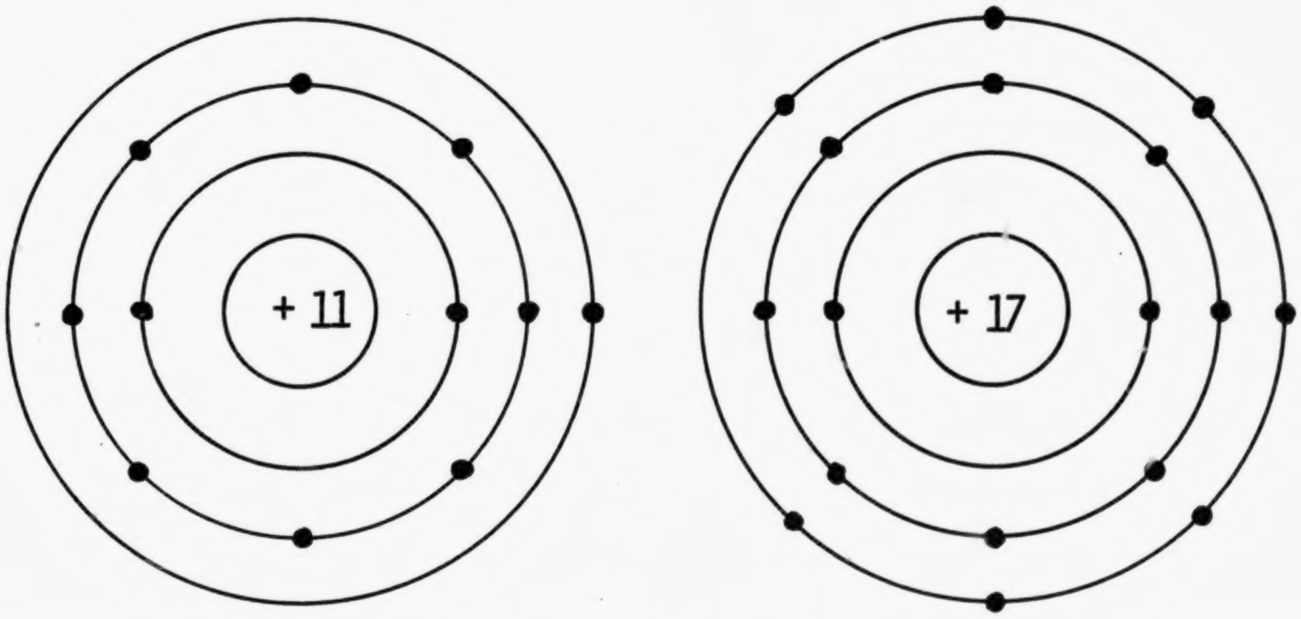
POSITIVE
ION



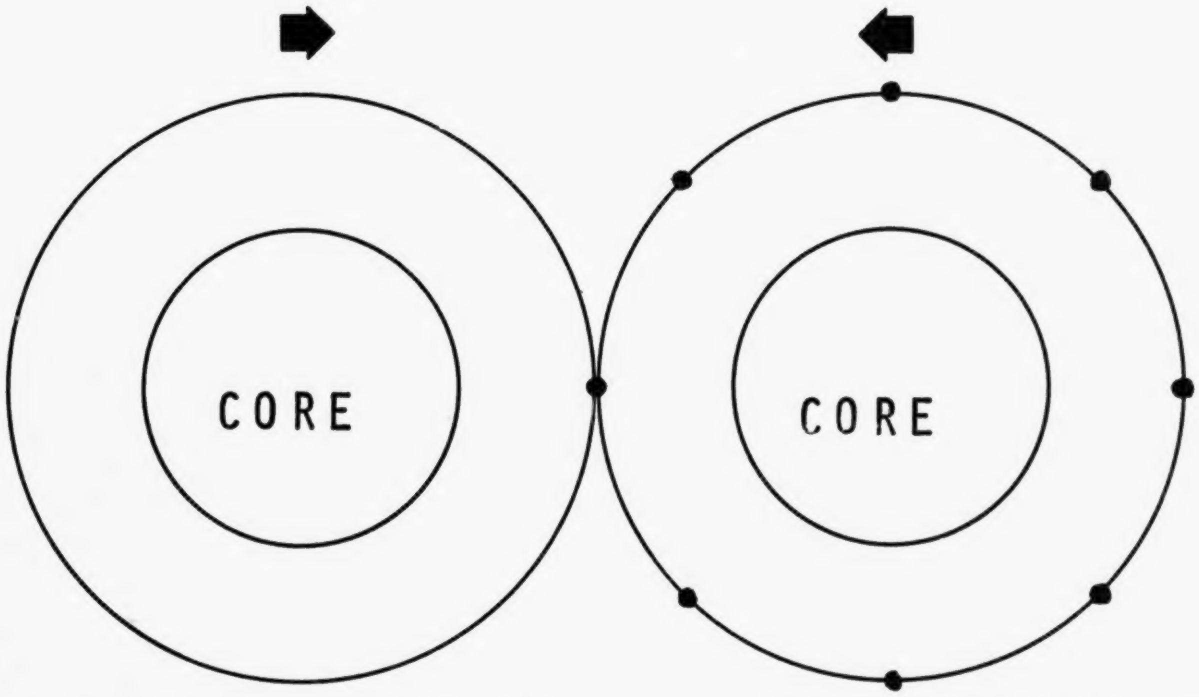
NEGATIVE ION

WHAT KIND OF CHARGE WILL ATTRACT A POSITIVE ION? A NEGATIVE ION?

IONIC BONDING



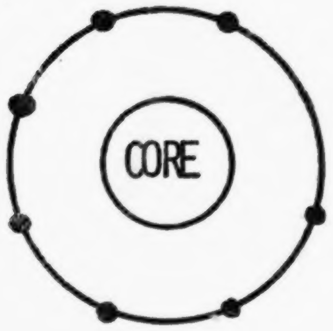
SODIUM CHLORINE



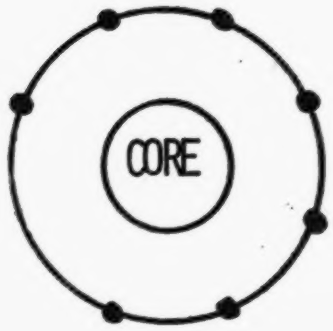
+ −

CHLORINE GRABS SINGLE ELECTRON TO ACHIEVE STABLE OCTET AND BECOMES NEGATIVE ION. SODIUM BECOMES POSITIVE ION. BOUND BY ELECTROSTATIC FORCES.

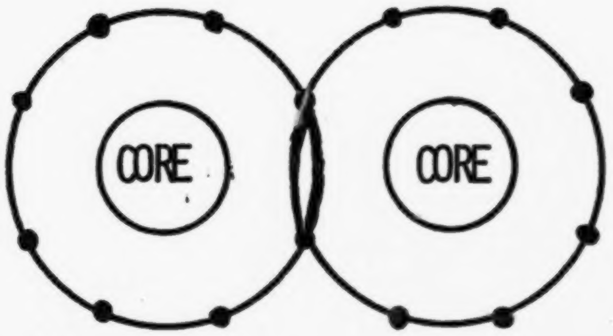
COVALENT BONDS



CHLORINE
7 ELECTRONS
IN VALENCE



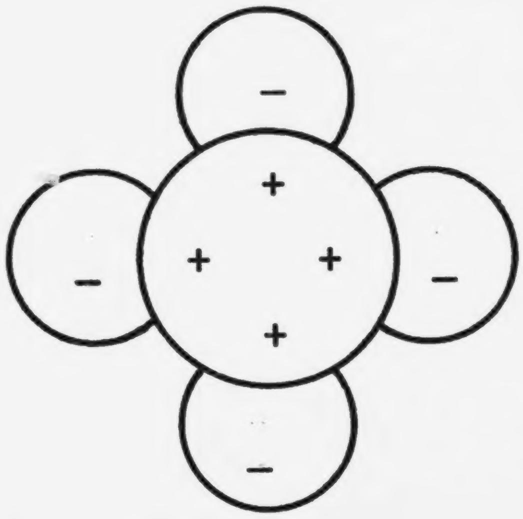
FLUORIDE
7 ELECTRONS
IN VALENCE



DOUBLE BOND: BY SHARING ONE ELECTRON EACH, BOTH ATOMS REACH STABLE OCTET AND WILL NOT BREAK BONDS EASILY.

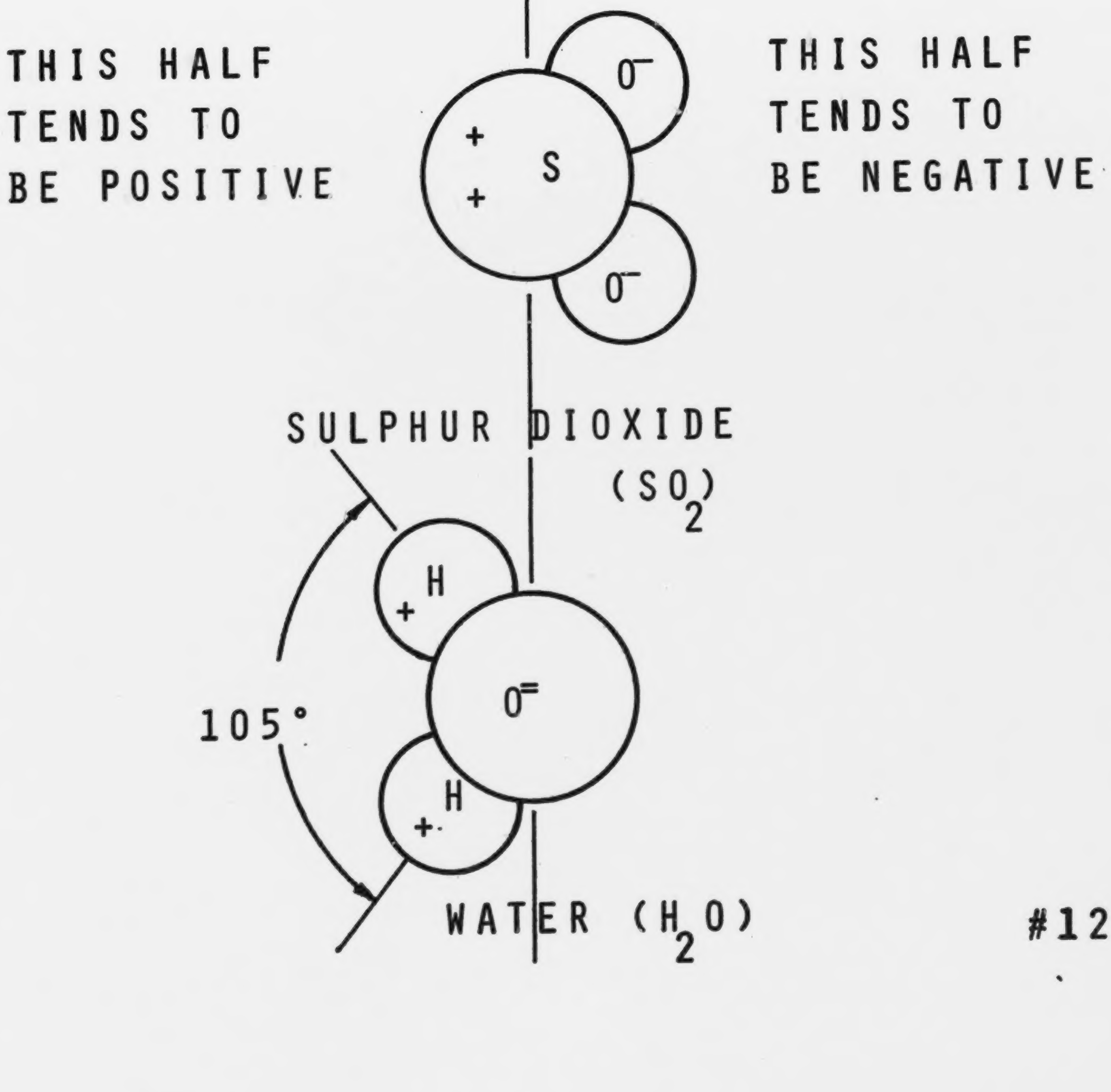
DISTRIBUTION OF CHARGE

NON-POLAR

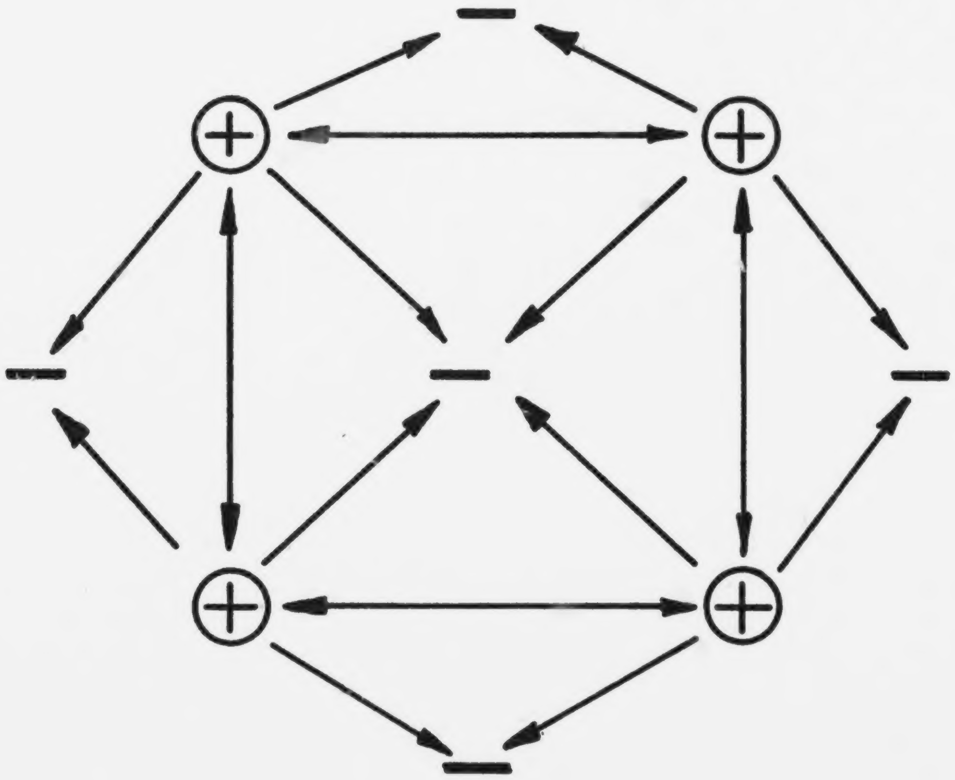


CHARGE
IS
SYMMETRICAL

POLAR COVALENT BOND


THIS HALF
TENDS TO
BE POSITIVE
THIS HALF
TENDS TO
BE NEGATIVE
O⁻
+
S
+
O⁻
SULPHUR DIOXIDE
(SO2)
+ H
O=
105°
+ H
WATER (H2O)

METALLIC BOND



— ELECTRON

⊕ ATOM WITHOUT VALENCE

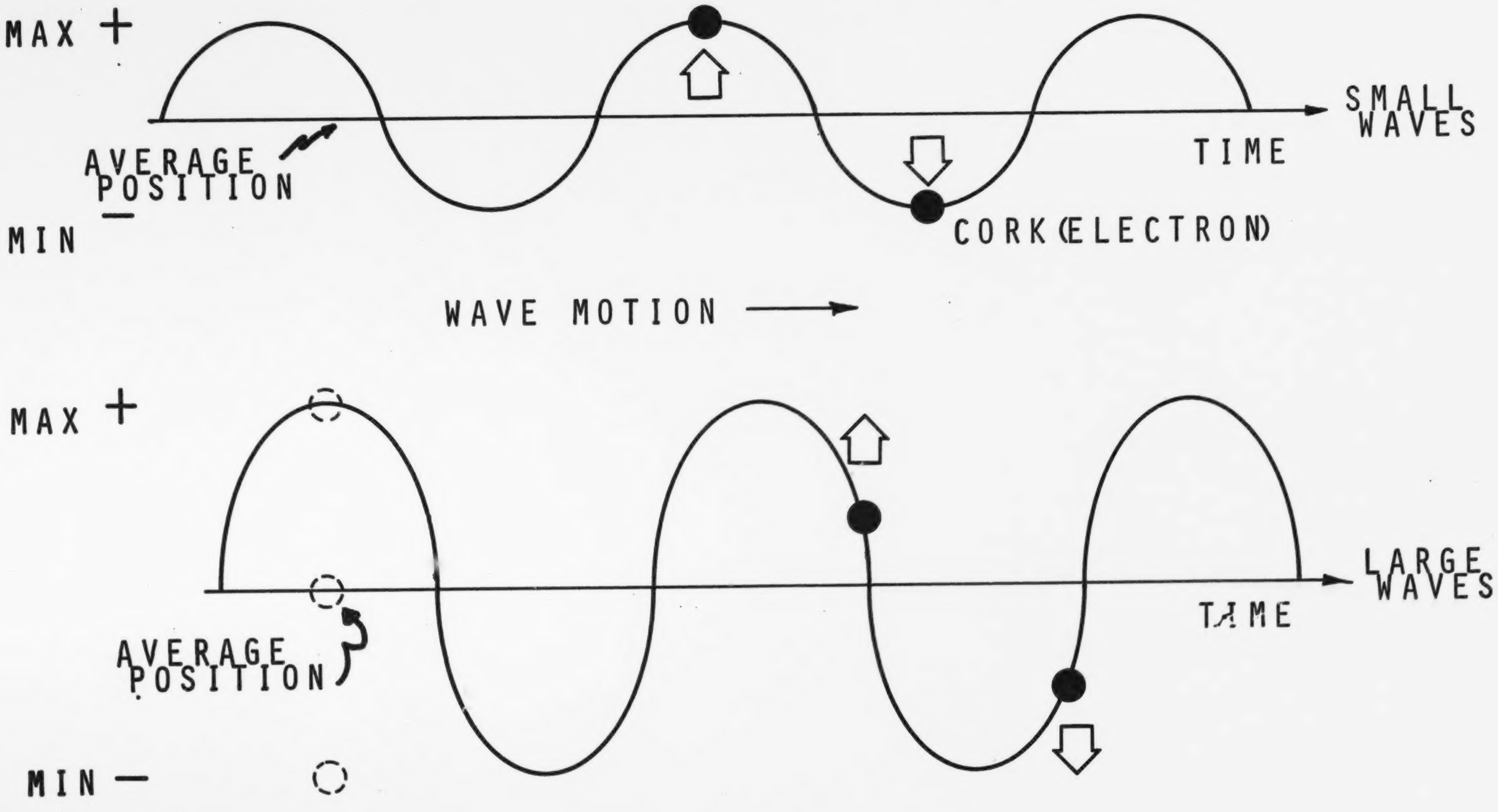
→ ATTRACTION FORCE

↔ REPULSION FORCE

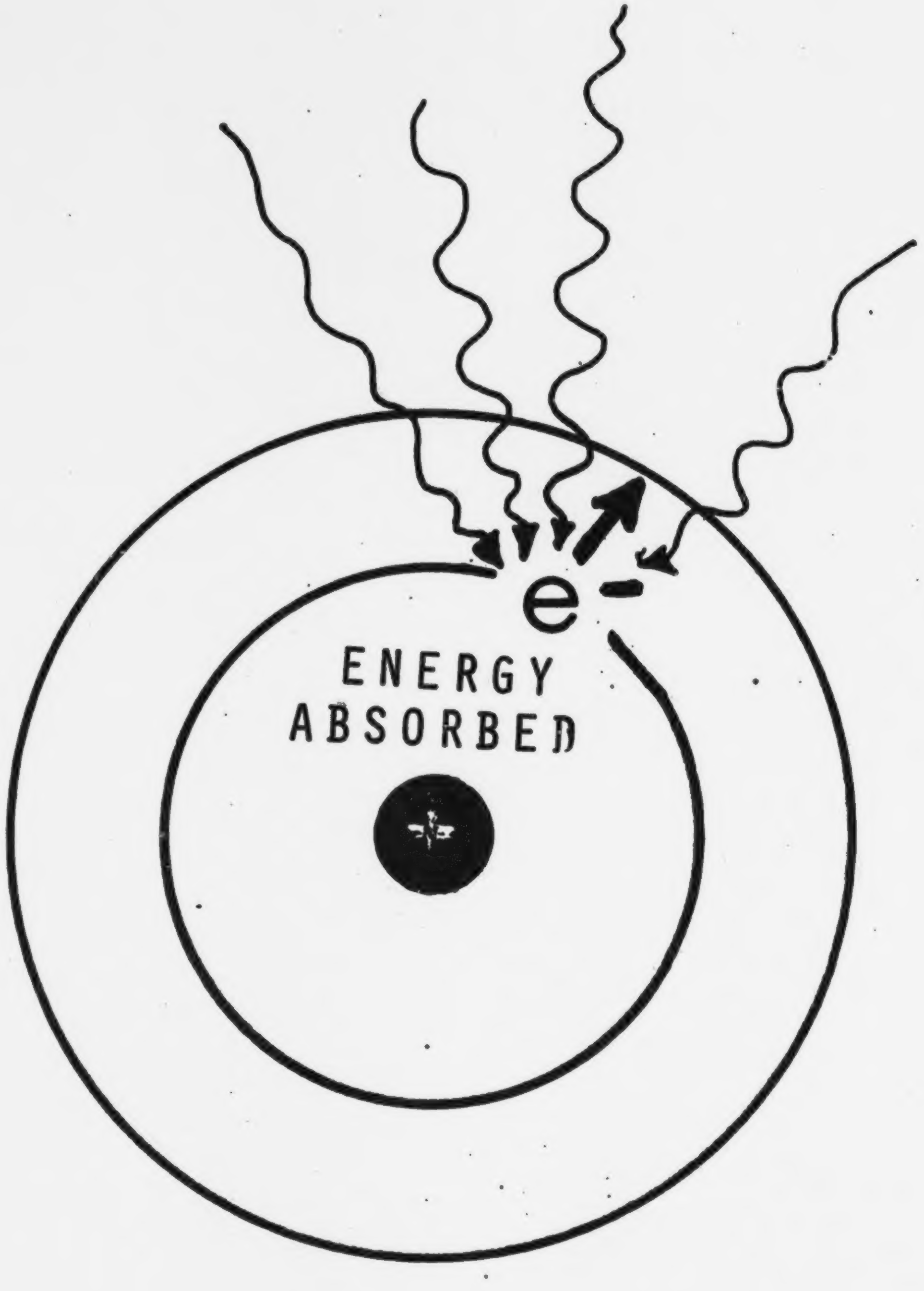
IRON

EACH ATOM HAS 2 VALENCE ELECTRONS. ELECTRONS FORM A CLOUD WHICH IS NEGATIVE. THESE ATTRACT POSITIVE CHARGES. POSITIVE IONS OR CORES ARE SURROUNDED BY FREE VALENCE ELECTRONS.

ABSORPTION OF THERMAL ENERGY
(ELECTROMAGNETIC RADIATION)


MAX +
MIN −
AVERAGE POSITION
SMALL WAVES
TIME
CORK (ELECTRON)
WAVE MOTION
MAX +
MIN −
AVERAGE POSITION
LARGE WAVES
TIME

LARGER WAVES (MORE HEAT) MORE ENERGY ABSORBED


e-
ENERGY
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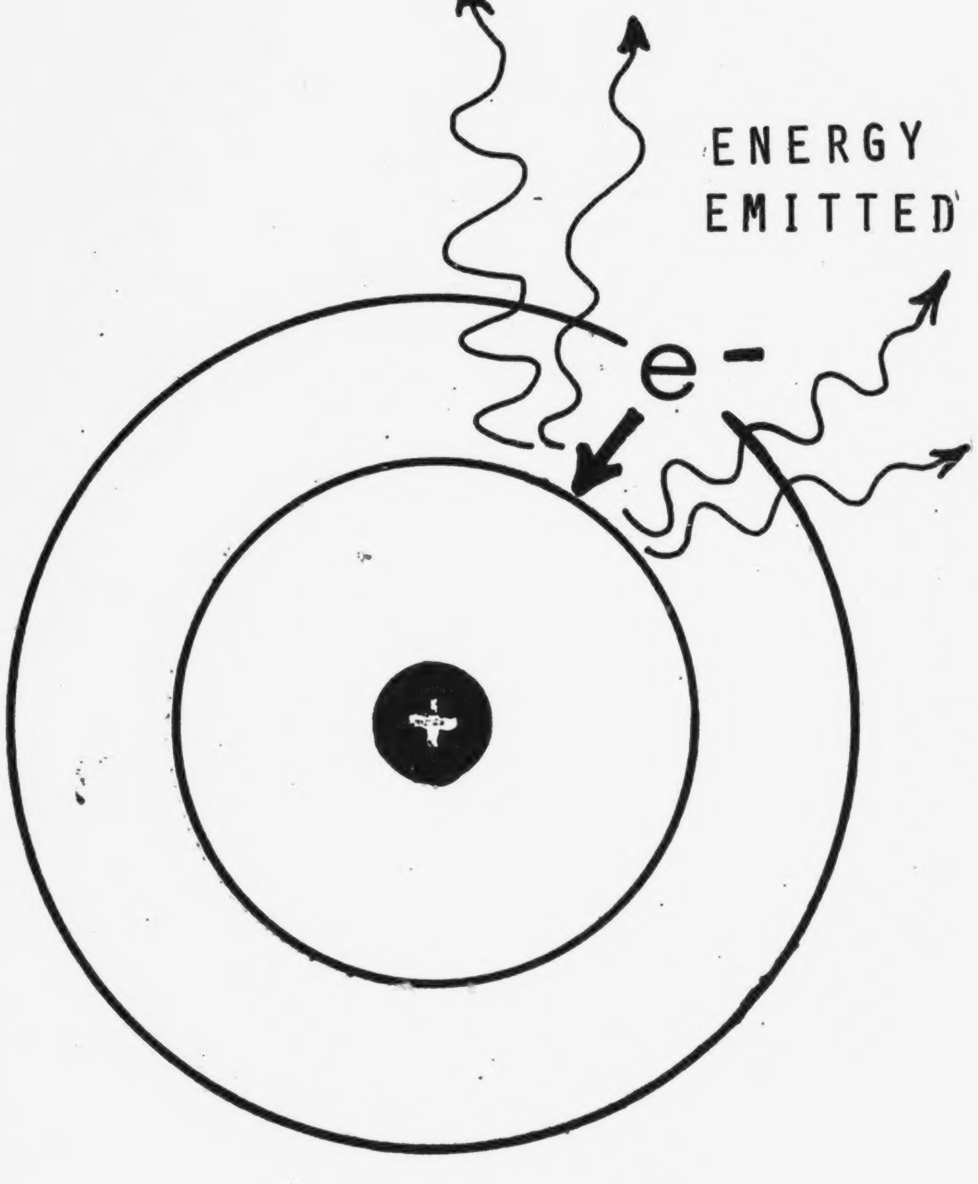
ENERGY
EMITTED
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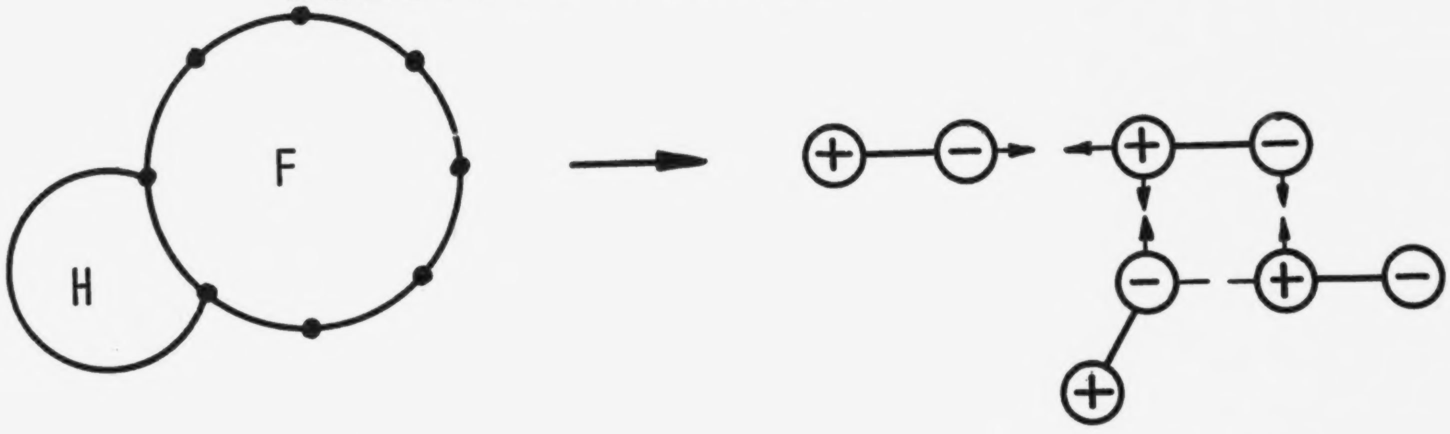
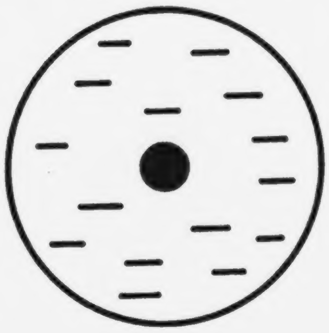
VAN DER WAALS FORCES OF MOLECULES ELECTRIC CHARGES

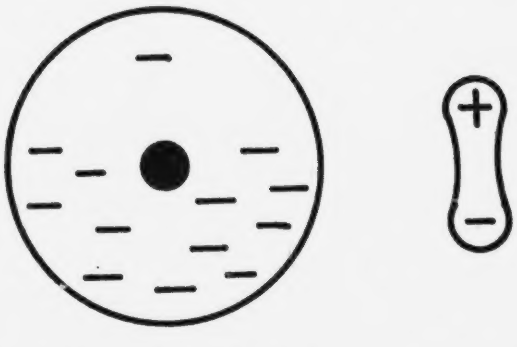


"DIPOLE"

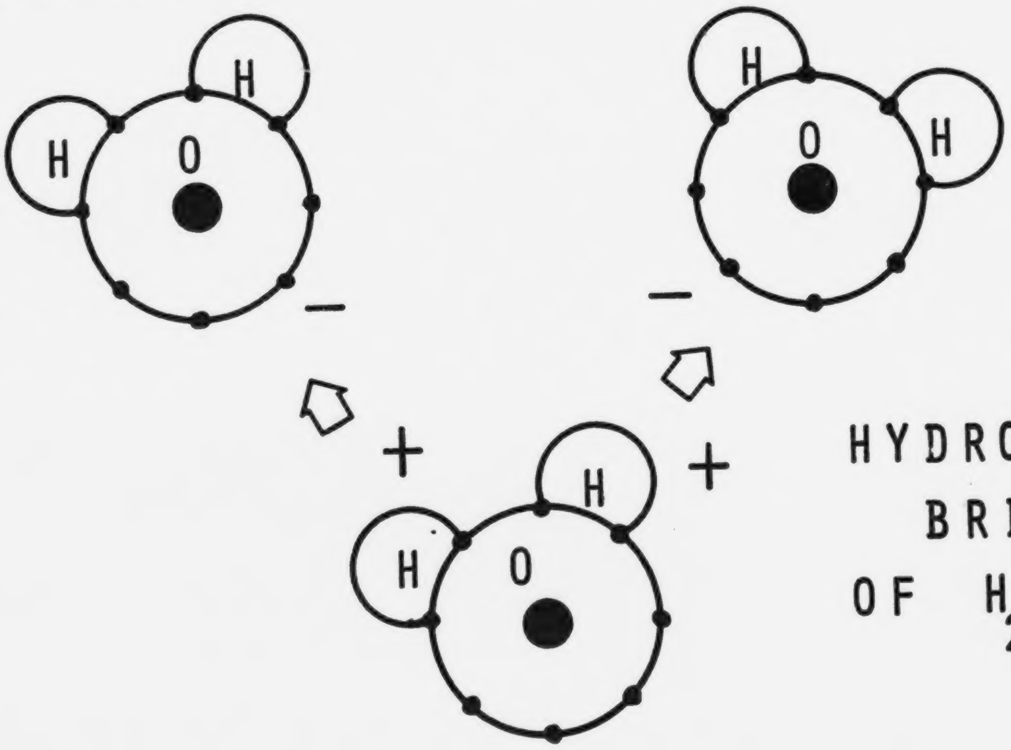
DISPERSION EFFECTS



UNIFORM
(CHARGE BALANCED)



POLARIZED
(CHARGE UNBALANCED)



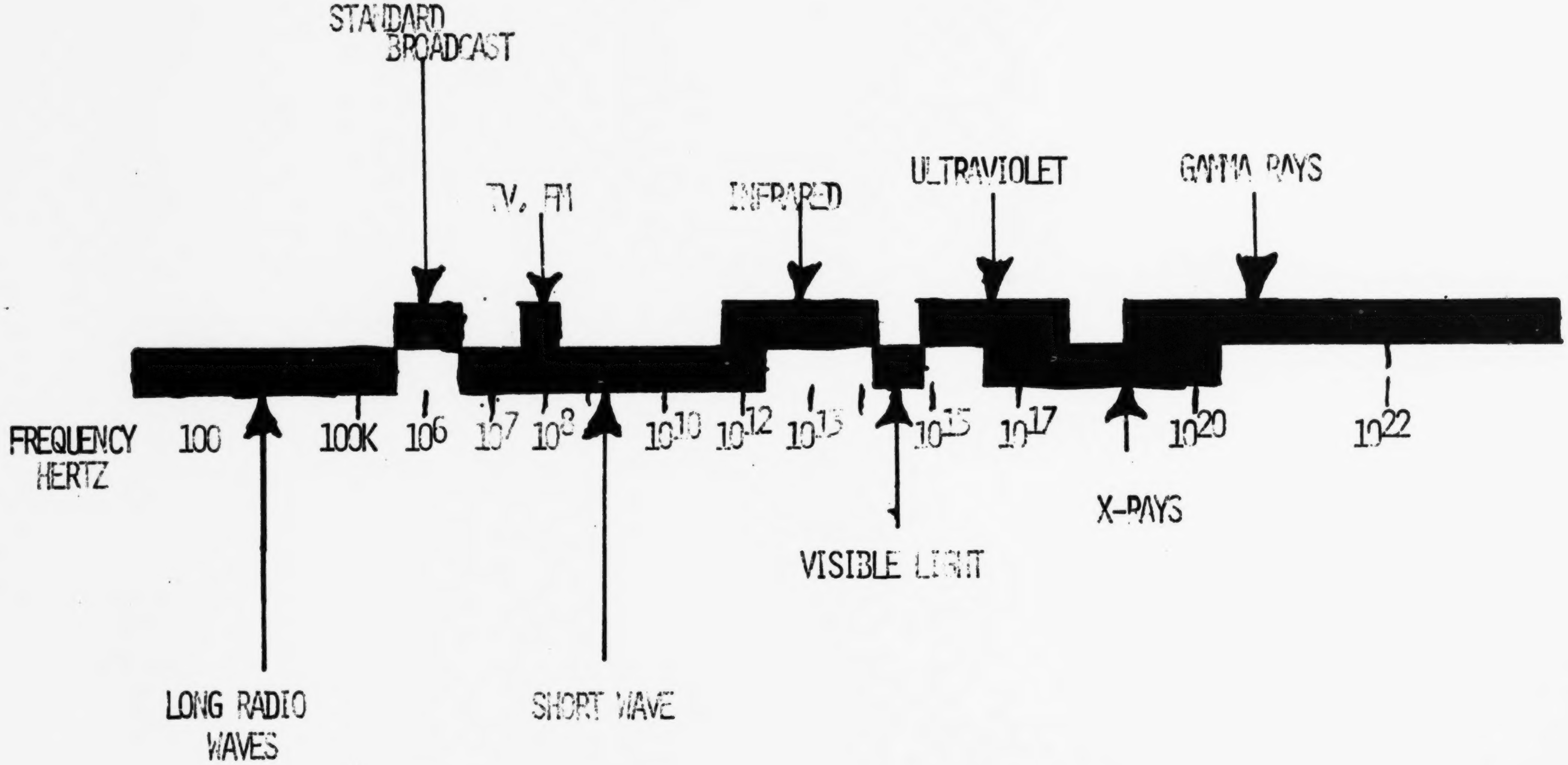
HYDROGEN
BRIDGE
OF H_2O

ELECTRODE POTENTIAL OF METALS

METAL ION	POTENTIAL
Li^{+} (BASE)	+2.96 (ANODIC)
K^{+}	+2.92
Ca^{2+}	+2.90
Na^{+}	+2.71
Mg^{2+}	+2.40
Al^{3+}	+1.70
Zn^{2+}	+0.76
Cr^{2+}	+0.56
Fe^{2+}	+0.44
Ni^{2+}	+0.23
Sn^{2+}	+0.14
Pb^{2+}	+0.12
Fe^{3+}	+0.045
H^{+}	0.000 (REF)
Cu^{2+}	-0.34
Cu^{+}	-0.47
Ag^{+}	-0.80
Pt^{4+}	-0.86
Au^{+} (NOBLE)	-1.50 (CATHODIC)

AN ACTIVE METAL WILL DESTROY ITSELF BY GIVING UP ELECTRONS TO A LESS ACTIVE METAL. THE ACTIVE OR DONOR METAL IS CALLED THE ANODE - THE ACCEPTOR IS CALLED THE CATHODE.

ELECTROMAGNETIC SPECTRUM


STANDARD
BROADCAST
TV, FM
INFRARED
ULTRAVIOLET
GAMMA RAYS
FREQUENCY
HERTZ
100
100K
10^6
10^7
10^8
10^{10}
10^{12}
10^{13}
10^{15}
10^{17}
10^{20}
10^{22}
X-RAYS
VISIBLE LIGHT
LONG RADIO
WAVES
SHORT WAVE

METALS

INDUSTRIAL MATERIALS STUDY

Course Outline

INDUSTRIAL METALS AND ALLOYS

Unit I. Structure of Metals
- A. Nature of Matter
  - 1. Atomic Structure - Atoms and Elements
  - 2. Table of Elements
  - 3. Crystal Bonds and Nature of Interatomic Forces
  - 4. Space Lattice and Crystal Structure
    - a. Types of Space Lattice
    - b. Miller Indices (slip planes and defects in crystals)
    - c. Analysis of Crystals by Means of X-ray Diffraction
    - d. Grain Growth
- B. Properties of Metals and Alloys
  - 1. Classes of Properties (chemical, physical, mechanical, etc.)
  - 2. Loading Systems and Material Failure (tensile, stress strain, etc.)
- C. Chemistry of Metals, Solid Solutions
  - 1. Solute Atoms
  - 2. Solvent Atoms
  - 3. Substitution Solid Solutions
  - 4. Interstitial Solid Solutions

Unit II. Solid State Changes in Metals
- A. Allotropic Changes
- B. Recrystallization and Recovery
- C. Age Hardening
- D. Work Hardening
  - 1. Plastic Deformation
  - 2. Dislocation Theory
  - 3. Cold Working
- E. Heat-treating

Unit III. Phase Diagrams
- A. Definition of Phase
- B. Constituents and Micro-constituents
- C. Components
- D. Equilibrium Diagrams
- E. The Iron-Carbon Diagram and others

Unit IV. Ferrous Metals

Identification and Definition
- A. Meteoric Iron and Iron Content of Earth

B. Review of Periodic Chart - Atomic Structure
C. Physical Chemical and Mechanical Properties of Pure Iron
    1. Relative Reactiveness (susceptibility to corrosion)
    2. Density
    3. Specific Gravity
    4. Magnetic Properties
    5. Thermal and Electrical Conductivity
    6. Melting Point
    7. Relationship to Electro-motive or Electro-chemical series

Unit V. The Structure and Composition of Cast Irons; Malleable, Ductile or Nodular, and Gray Cast Iron
A. Common Cast Iron Structures
B. Composition
C. Chemical and Physical Properties
D. Modifications
    1. Use of Innoculents and Alloys
    2. Heat Treating

Unit VI. The Structure and Composition of Carbon Steels, Low, Medium, and High
A. Diffusion
    1. Dendritic Segregation
    2. Interstitial Diffusion
B. Grains and Grain Boundaries
    1. Equiaxed Grains
    2. Elongated Grains
    3. Grain Boundaries
    4. Molecular Migration
C. Heat Treatment: (Hardening)
    1. Allotropic Changes - Crystalline Structure
    2. Transformation Levels
    3. Metallography and Grain Growth (Pearlite, Ferrite, Martensite)
    4. Time Temperature Transformation Curves
    5. Quenching Media
D. Heat Treatment: (Normalizing, Annealing, Tempering)
E. Heat Treatment, Surface Hardening
    1. Carburizing
    2. Nitriding
    3. Cyaniding

Unit VII. Alloy Steels
A. Purposes for Alloying Steels

- B. Effects of Alloying Elements Upon:
  - 1. Ferrite
  - 2. Carbide
- C. Influence of Alloying Elements on/in
  - 1. Iron -- Iron Carbide Diagram
  - 2. Tempering
  - 3. Hardenability
- D. Common Alloy Elements, Specific Effects, and Application
  - 1. Nickel
  - 2. Chromium
  - 3. Nickel-chrome
  - 4. Manganese
  - 5. Malybdenum
  - 6. Tungsten
  - 7. Vanadium
  - 8. Silicon
  - 9. Stainless
- E. Microstructures of Alloy Steels

Unit VIII. Non-Ferrous Alloying

- A. Purposes for Alloying Non-Ferrous Base Metals
- B. Properties
  - 1. Physical (constants)
    - a. Density
    - b. Crystalline Type
    - c. Atomic Spacing
    - d. Specific Heat
    - e. Melting Point
  - 2. Chemical
  - 3. Mechanical
    - a. Hardness
    - b. Strength
    - c. Etc.
  - 4. Electrical
- C. Material Modifications
  - 1. Alloying
  - 2. Heat Treatment
  - 3. Working Below Recrystallization
  - 4. Working Above Recrystallization
- D. Common Non-Ferrous Bases
  - 1. Copper
  - 2. Aluminum
  - 3. Lead
  - 4. Tin
  - 5. Magnesium
  - 6. Zinc

Unit IX. Tool Steels and Cutting Tool Materials
- A. Classification of Tool Steels
- B. Comparative Properties
    - 1. Toughness
    - 2. Red Hardness
    - 3. Wear Resistance
    - 4. Non-Deforming
    - 5. Machinability
    - 6. Safety in Hardening
    - 7. Resistance to Decarburization
- C. Tool Steels
    - 1. Carbon (High)
    - 2. High Speed Steel
        - a. Molybdenum Group (M)
        - b. Tungsten Group (T)
    - 3. Tungsten Carbides
    - 4. Ceramic
    - 5. Cermets
- D. Comparison Studies of Properties of All Tool Materials.

Unit X. Metal Powders
- A. Health and Medical
    - 1. Dental Fillings -- Gold and Silver
    - 2. Dietary -- Iron Rich Foods
    - 3. Disinfectants
    - 4. Water Purification
    - 5. Medicine -- Insulin - Zinc - Aluminum - Iron
- B. Joining and Surfacing
    - 1. Electrode Coatings
    - 2. Brazing Filler Materials
    - 3. Soldering Filler Materials
    - 4. Hard Surfacing -- Wear and Corrosion Resistance
- C. Agriculture
    - 1. Seed Cleaning
    - 2. Fungicides
    - 3. Pest Control (Poisons)
- D. Paints and Pigments
    - 1. "Gilt" Paints
    - 2. Metallic Flake Paints
    - 3. Coloring Pigments -- Ink and Paints
    - 4. Corrosion Resistant Paints -- Aluminum,Zinc
- E. Sentered Products
    - 1. Powdered Metallurgy
    - 2. Cermets
- F. Miscellaneous
    - 1. Materials Testing (Magnetic Particle)

2. Radiation Shielding
3. Magnetic Audio and Video Tape
4. Lubricants
5. Incadescent and Fluroescent Lights
6. Electronic Printed Circuits

Unit XI. Corrosion and Protection of Metals
- A. Classifications of Corrosion
    1. Chemical Corrosion
        - a. Gaseous Corrosion; Corrosion in Non-electrolytes
    2. Electrochemical Corrosion
        - a. Corrosion in Electrolytes; soil, ground, or underground corrosion; atmospheric; contact; stress; impingement; erosion; bicorrosion
    3. General Corrosion
        - a. Uniform; Non-uniform; Selective-Structural Corrosion
    4. Local Corrosion
        - a. Stain; Pitting; Pinpoint; Subsurface; Intercrystalline; Cracking; Subsurface
- B. Methods of Protecting Metals Against Corrosion
    1. Treatment of the Medium in Which Corrosion Takes Place
    2. Electrochemical Protection
    3. Protective Coatings

Note: The following outline does not cover a particular material, but rather a fabrication technique for several different materials. The property changes are quite significant when materials are treated in this manner. This outline may serve as an example of additional units which may be added to this study of industrial metals and alloys by teachers in order to suit their own particular needs.

Unit XII. Honeycomb Materials
- A. Sandwich Panels Structure
    1. Designs
    2. Primary Parts
- B. Materials for Honeycomb Structure
    1. Facing Selection
    2. Adhesive Selection
    3. Honeycomb Core Selection
- C. Characteristics of Honeycomb
- D. Varieties of Honeycomb

E. Properties of the Material
F. Joints in Honeycomb Core
G. Applications of Honeycomb Materials
H. Sources of the Material

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Arthur E. Muller
Stout State University
Menomonie, Wisconsin

INSTRUCTIONAL LEVEL: College

TITLE: Adhesives for Metals

PRESENTATION TIME: 2 hours

INTRODUCTION:

The use of adhesives for joining and fabricating metals is relatively new in terms of the length of time in use. The first attempts were made with phenolic resins in the 1930's. Since then the epoxy family (1950's) and a few others have come into use. Adhesives have found wide use throughout the field of materials. Few of us realize how dependent we are on "glue," and many would probably hesitate to recommend gluing anything in a really critical application. If you don't have faith in adhesives then consider "bonded" brake linings or the metal skin on jet aircraft. The study of adhesives will reveal that this is indeed a very reliable means of joining materials when a few principles are observed as with any fastening system.

OBJECTIVES:

To familiarize the student with:
- The Principles of Bonding - (Visual Aid 2, 3, 4, 5, 6)
- Types of Adhesives Used - (Visual Aid 1)
- Present Applications of Adhesives
- The Future of Adhesives

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:
- Plastics
- Physics
- Chemistry

USE IN INDUSTRY:

Metal To Metal

- Aircraft Skin
  - (aluminum B-58)
- Automotive
  - Floor pans
  - Hoods
  - Trunk Lids
  - Roof Panels
- Electric Motor Rotors
- Honeycombs
- Magnets to die cast zinc
- Unlike metals

Metal To NonMetal

- Brake Linings
- Clutch Facings
- Transmission Bands
- Glass to Frame
- Engine Mounts
- Weather Strip
- Trim - Vinyls
- Insulation
- Abrasives

MATERIALS AND EQUIPMENT:

Sheet Metal Test Strips cut to appropriate size for available test apparatus.

Tensile Test Apparatus for tensile, shear, and peel tests. (Visual Aid 7)

Adhesives - Scotch Grip Brank Contact Cement 1357
Scotch Grip Brank Industrial Adhesive 847
Scotch-Weld Brank Structural Adhesive 2214
(These adhesives by 3-M Company)
Any other adhesive may be used as recommended by manufacturer.

EDUCATIONAL MEDIA:

Films: Contact adhesive manufacturers for suitable films

Transparencies: For overhead projector and 35mm slides may be easily developed from descriptive literature and technical data sheets.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Some adhesive materials use solvents that may be volatile, some produce toxic fumes, and others may cause skin or eye irritation. Check on the type you intend to use and handle accordingly.

PRESENTATION: Structural Adhesives for Metals
(Visual Aid #1)

Ceramics:

A recently developed (1961) adhesive that will bond tungsten, molybdenum, platinum, vanadium, beryllium, glass and ceramics. Ceramics adhesives are noted for their wide service temperature range, -250° F. to 1500° F. The cement is mixed with a liquid suspension medium to a past consistency, applied, and cured by firing at 900° F. to 1600° F. This material is capable of producing vacuum tight seals. Various formulations make it possible to bond materials with different coefficients of thermal expansion. (Brand name of one product: Metl-Bond X-800, Mfg. by Narmco Industries, Costa Mesa, California)

Cyanoacrylate:

A very versatile in bonding a variety of adherends. Curing (polumerization) occurs upon the application of pressure in a very short time (10 seconds - 10 minutes depending upon adherend.) Moisture in the air acts as a catalyst to polymerization. The bond strength increases with age. The strength may be reduced by high humidity, prolonged immersion in water, acids or alkaline solutions. Service temperature range is from -65° to 180° F. (Brand name of one product: Eastman 910, Mfg. by Eastman Chemical Products, Inc., Kingsport, Tennessee

Polyurethanes:

Practical to use on metal to metal bonding of steel, aluminum, magnesium, stainless steel, beryllium, uranium, and nonmetals to themselves and each other. Special formulations are used in critical aircraft and space applications. Curing cycle - several weeks at room temperature to an hour at 300° F. - 350° F. at pressures of 5 to 500 psi. Shear strength as high as 6,000 psi at room temperature on metal to metal bonds. Bonds are flexible, have good peel resistance, good shock and vibration resistance, and resistance to most acids, alkalis, solvents, oils, aliphatic compounds. Is sensitive to high humidity conditions. Bond strengths maintained from -100° F. to 200° F. (Brand name: APCO 1252 by Applied Plastics Co., Inc. El Segundo, California. Mondur CB-75 by Mobay Chemical Co., 1815 Washington Road, Pittsburgh, Pennsylvania.)

Epoxy Based Adhesives:

A group of thermosetting resins that polymerize, initiated by a catalyst producing a exothermic reaction. The catalyst may be a amine, acid, or a copolymer resin. The choice of curing agent affects the work life of the adhesive and the properties of the cured bond. Will cement a wide variety of materials, metal to metal, metal to non-metal. It has high tensile but low peel strength. May be highly modified with additives.

Epoxy-Phenolics:

Formulation of two thermosetting resins. Suitable for high temperature service (-67° F. to 500° F.) over extended periods of time. Used to bond stainless steel, titanium, beryllium, and honeycomb sandwich structures. Curing temperature is 325° F. to 350° F. for 40 minutes to one hour under pressure of 5 to 100 psi depending upon formulation. High shear strength (2500 to 3800 psi), service temperature range (-67° F. to 500° F.) Nitrile elastomer additive improves peel strength. (Brank name of one product: Metl-Bond - 302 by Narmco Industries Inc. ScotchWeld Af 32 by #3-M Co., St. Paul, Minnesota)

Epoxy-Polyamides:

A modified epoxy that is versatile for rigid and flexible materials. Has good shear, peel, and impact strength, but low creep resistance. Varying the formula affects curing rates and flexibility. Curing rate is slow (3-5 days at room temperature) permitting longer pot life. Service temperature range (-70° F. to 150° F.) (Brand name of one product: Versamid 100 by Chemical Division of General Mills Inc.)

Epoxy-Polysulfide:

A modified epoxy for concrete to metal applications. Curing time is 8-24 hours at 70° F. to 90° F., 20 minutes at 150° F. The shear strength of steel/concrete is about 1,000 psi. The shear strength drops rapidly as temperatures rise above 100° F. (Brand Name: EC 1751/52, by 3-M Co., St. Paul, Minnesota. Resilith, by Borden Chemical Co., New York, New York.)

Epoxy-Silicones:

An organic polymer modified epoxy for fairly high temperature (to 900° F. intermittently) service. Successfully used with stainless steel and titanium for airframe

fabrication. Usually applied as asbestos fabric supported tape. Good resistance to heat and oxidation at elevated temperatures (to 900° F.). Curing cycle and range rather lengthy and involved. Curing temperature 300° F. at 50 psi, then temperature raised to 600° F. and 75 psi for 3 hours, finally post-cure 24 hours at 500° F.
(Brand name: Metl-Bond 311, by Narmco Industries, Inc.)

Phenolic Based Adhesives:

Practically all structural adhesives for metals are phenolic resins modified by additives of rubber, epoxies, and vinyls. Filler composed of metallic and inorganic substances are used. The major types are discussed individually in following paragraphs.

Phenolic-Nitriles:

Also called nitrile rubber. Frequently used in tape supported form but also available as a liquid. Has good structural stability, service temperature range (-70° F. to 500° F.) Resistant to a wide variety of chemicals,oils, fuels and solvents. Serves well for brake linings, fuel tanks, air frames, and helicopter blades. Curing time is 2 hours at 300° F. or 8 minutes at 425° F. with clamping pressures 10-200 psi.
(Brand name: Scotch Grip Brand Industrial Adhesive 847 by 3M, St Paul, Minnesota.)

Phenolic-Neoprenes (Chloroprene):

A modified phenolic primarily intended for bonding aluminum and magnesium to themselves or each other. Highly resistant to vibratory fatigue and low temperature (-70° F.) conditions. Usually used in supported tape form; may require a surface primer. Curing system: air dry 30 minutes; an additional 45 minutes at 180° F. in service.
(Brand name: Metl-Bond 303, by Narmco Industries)

Phenolic-Vinyls:

A formulation of phenolic (thermosetting) and vinyls (thermoplastic). Generally available in emulsion, tapes or as two part adhesives (liquid phenolic resin, and vinyl powder). Suitable for honeycomb sandwich construction of metal - nonmetal. Curing ranges 15-30 minutes at 300° F. with contact pressure to 100 psi pressures. Service temperatures -67° F. to 100° F.+, 50% loss of strength at 180° F.
(Brand name: Duro-Lok 2001 by Structural Products Division of National Starch Products, Inc., 750 - 3rd Ave., New York, New York. Narm-Tape by Narmco Industries.)

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Apply principles of bonding to prepared specimens.
Run tensile, shear, and peel tests
Compile test data

UNIT EVALUATION:

Tests; Written and/or oral reports on:
- Principles of Bonding
- Setting and Curing Mechanisms
- Joint Design
- Testing Applications

DEFINITION OF TERMS:

1. Adherend: A body which is held to another body by an adhesive.
2. Adhesion: The state in which two surfaces are held together by interfacial forces which may consist of valence forces or interlocking action, or both.
3. Adhesive: A substance capable of holding materials together by surface attachment.

REFERENCES:

1. Handbook of Adhesives, Irving Skeist ed., 1962, Reinhold Publishing Corp., New York, New York.
2. Concise Guide To Structural Adhesives, Werner H. Guttman, 1961, Reinhold Publishing Corp.
3. Materials In Design Engineering - Materials Selector Issue, 1966-67, Reinhold Publishing Corp.
4. Processes and Materials of Manufacture, Roy A. Lindeberg, 1964, Allyn & Bacon, Inc., 150 Tremont Street, Boston, Massachusetts.
5. 1967 Book of ASTM Standards, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ADHESIVES for METALS

Types:

EPOXY BASED:

- Phenolics
- Polyamides
- Polysulfides
- Silicones

PHENOLIC BASED:

- Nitriles
- Neoprenes
- Polyvinyl

OTHERS:

- Ceramic
- Cyanoacrylate
- Polyurethane

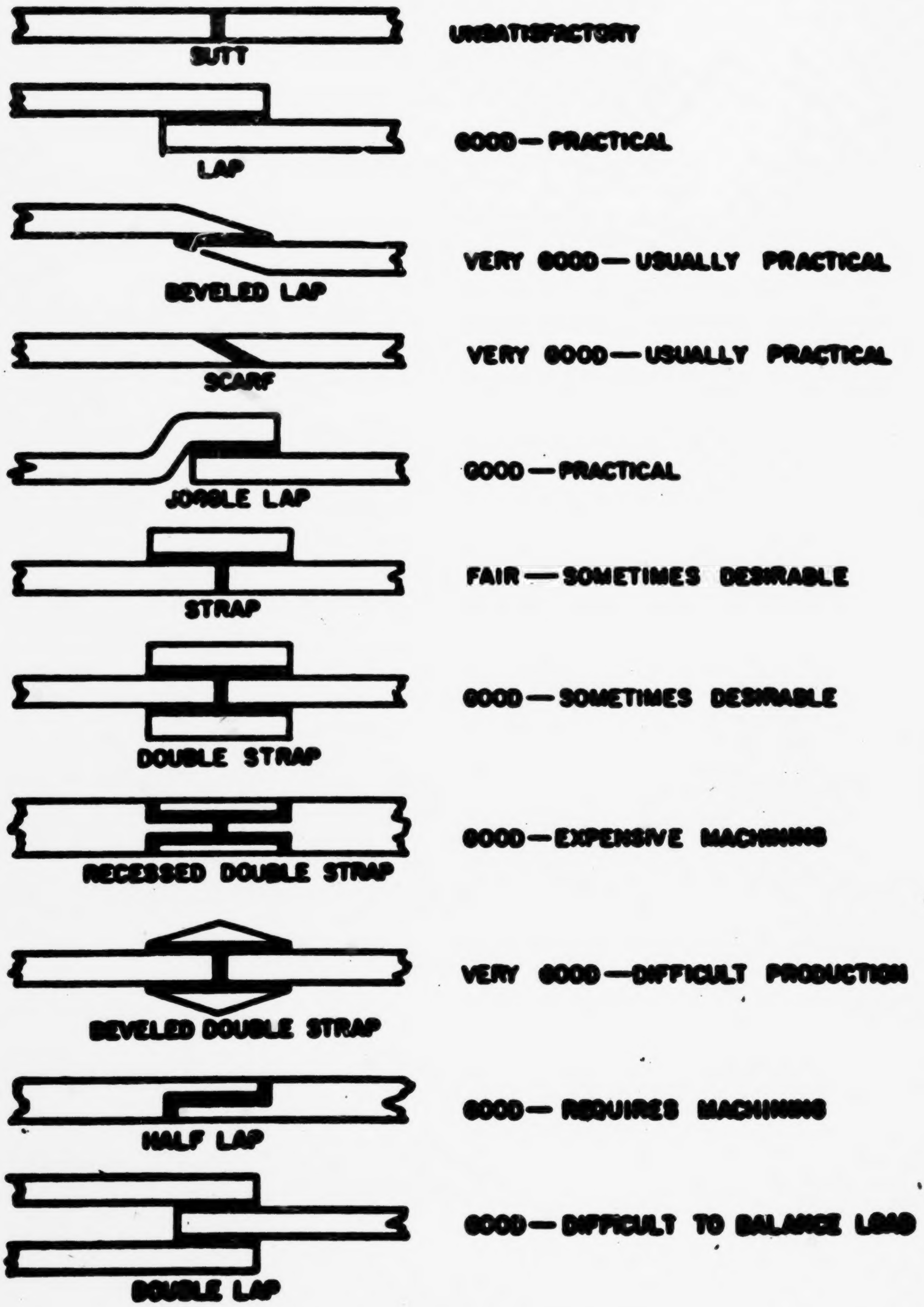
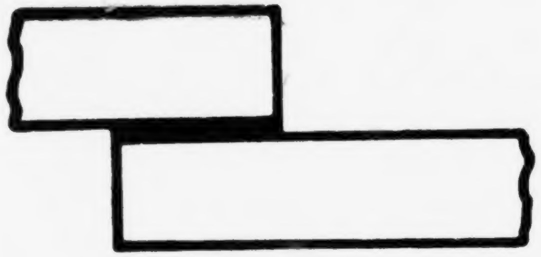
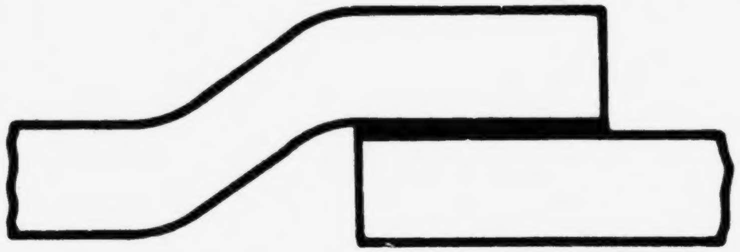

BUTT
UNSATISFACTORY
LAP
GOOD—PRACTICAL
BEVELED LAP
VERY GOOD—USUALLY PRACTICAL
SCARF
VERY GOOD—USUALLY PRACTICAL
JOGGLE LAP
GOOD—PRACTICAL
STRAP
FAIR—SOMETIMES DESIRABLE
DOUBLE STRAP
GOOD—SOMETIMES DESIRABLE
RECESSED DOUBLE STRAP
GOOD—EXPENSIVE MACHINING
BEVELED DOUBLE STRAP
VERY GOOD—DIFFICULT PRODUCTION
HALF LAP
GOOD—REQUIRES MACHINING
DOUBLE LAP
GOOD—DIFFICULT TO BALANCE LOAD

Fig. 14. Types of lap joints.

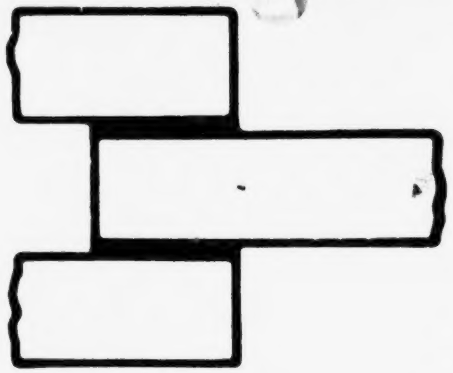
mu—2



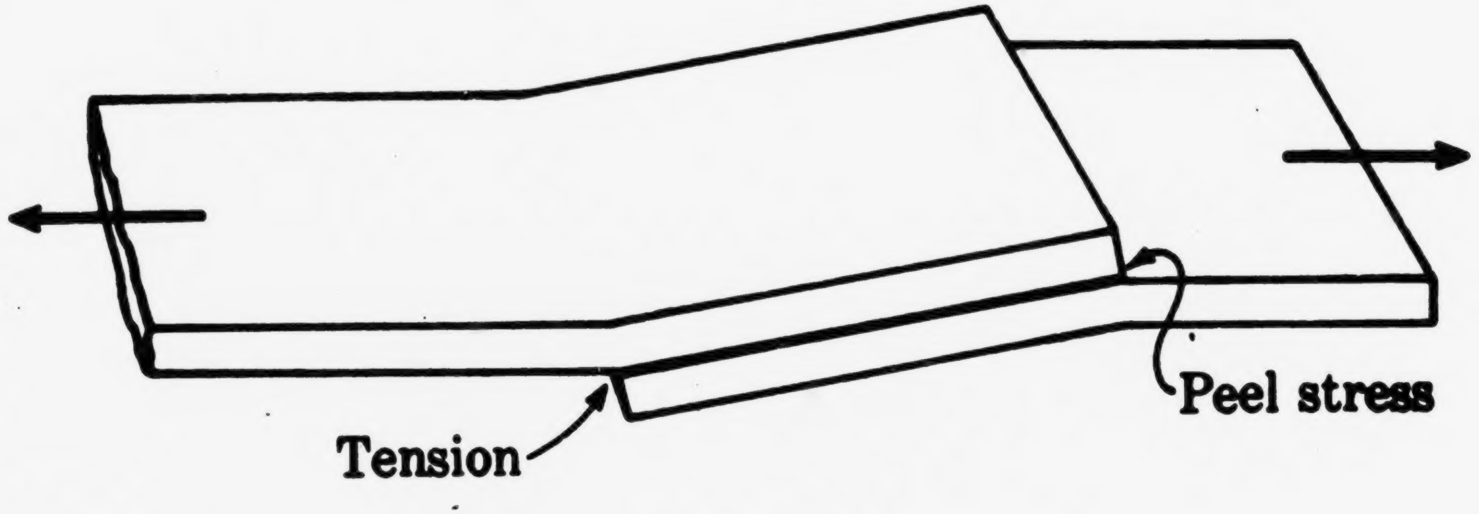
Conventional lap

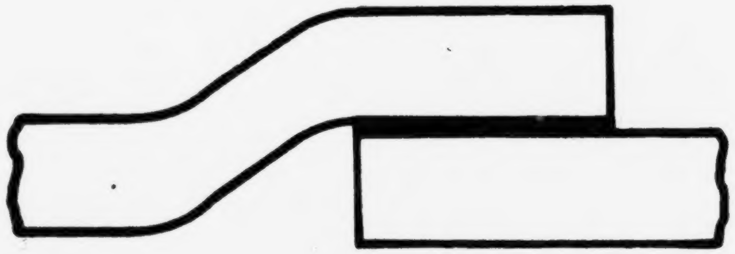


Joggle lap

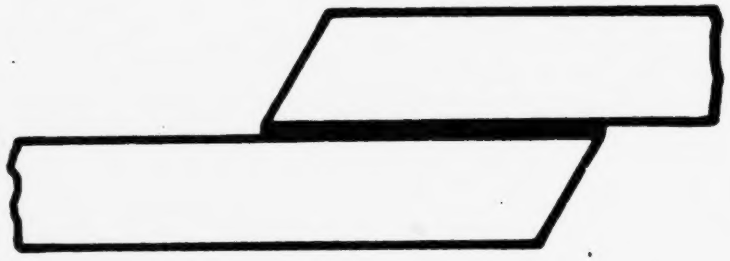


Double lap


Peel stress
Tension

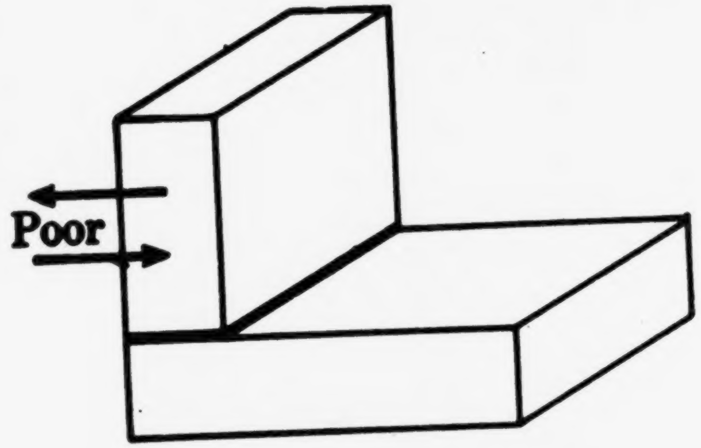


Joggle joint

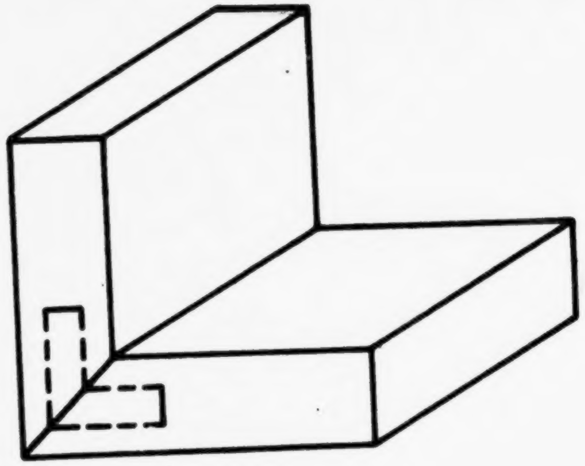


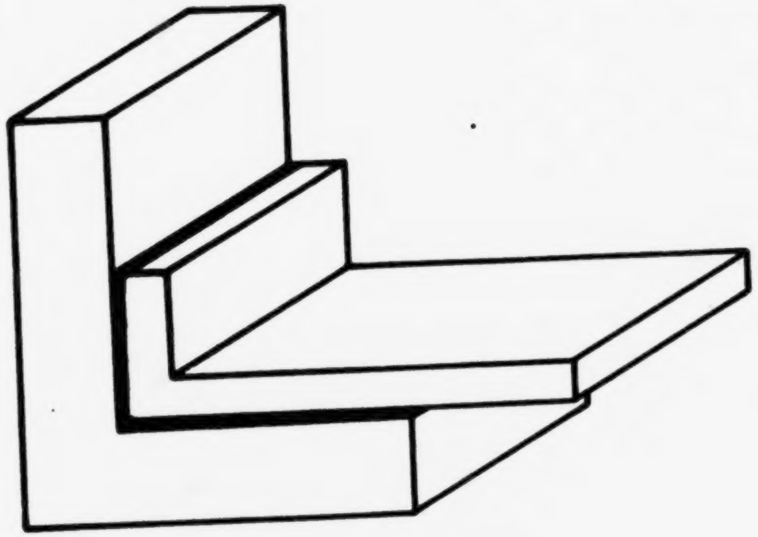
Beveled lap

mu—3



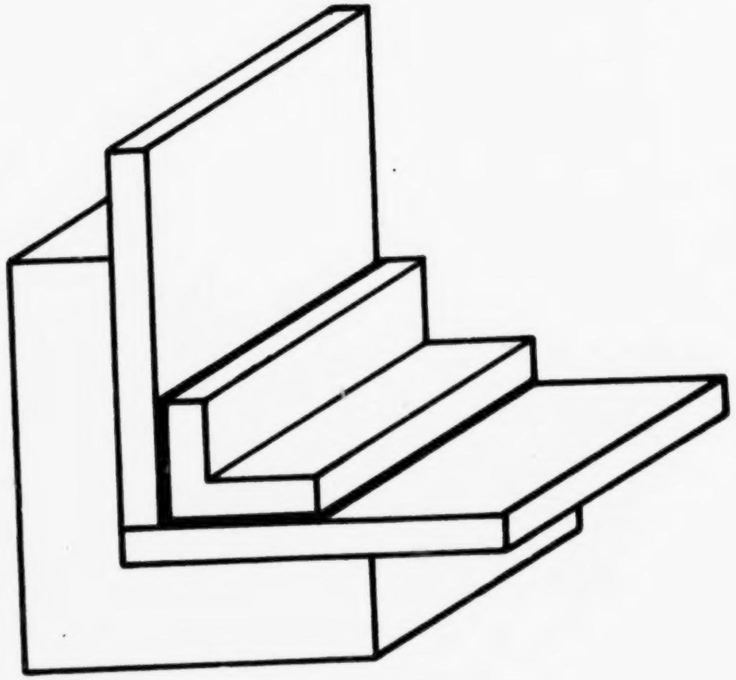
Basic corner joint





Angled corner joint

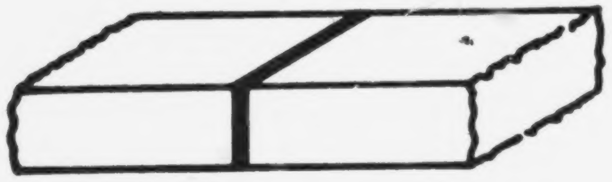
The angled corner joint provides greater adhesive area plus reinforcement to minimize the weakness of the joint.



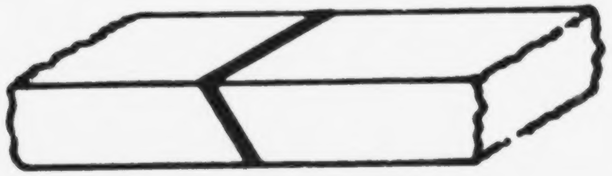
Reinforced corner

The reinforced corner is the strongest type, providing the most adhesive area and reinforcement.

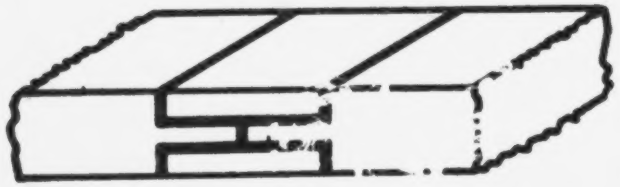
Adhesives



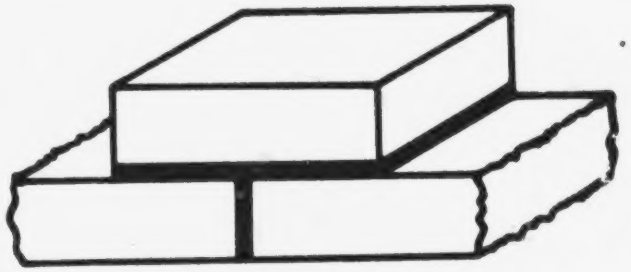
Butt—unsatisfactory



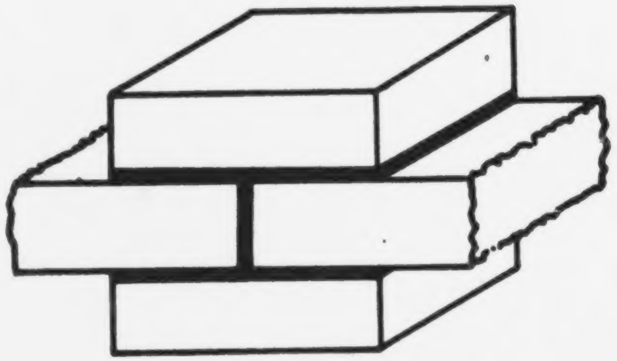
Scarf gives more joint
area but requires machining



Recessed double strap; large
adhesive area, but machining
cost is high



Single strap; fair
improvement over plain
butt joint



Double strap;
considerable surface increase

Fig. 15-10. Methods of improving adhesive butt joints.

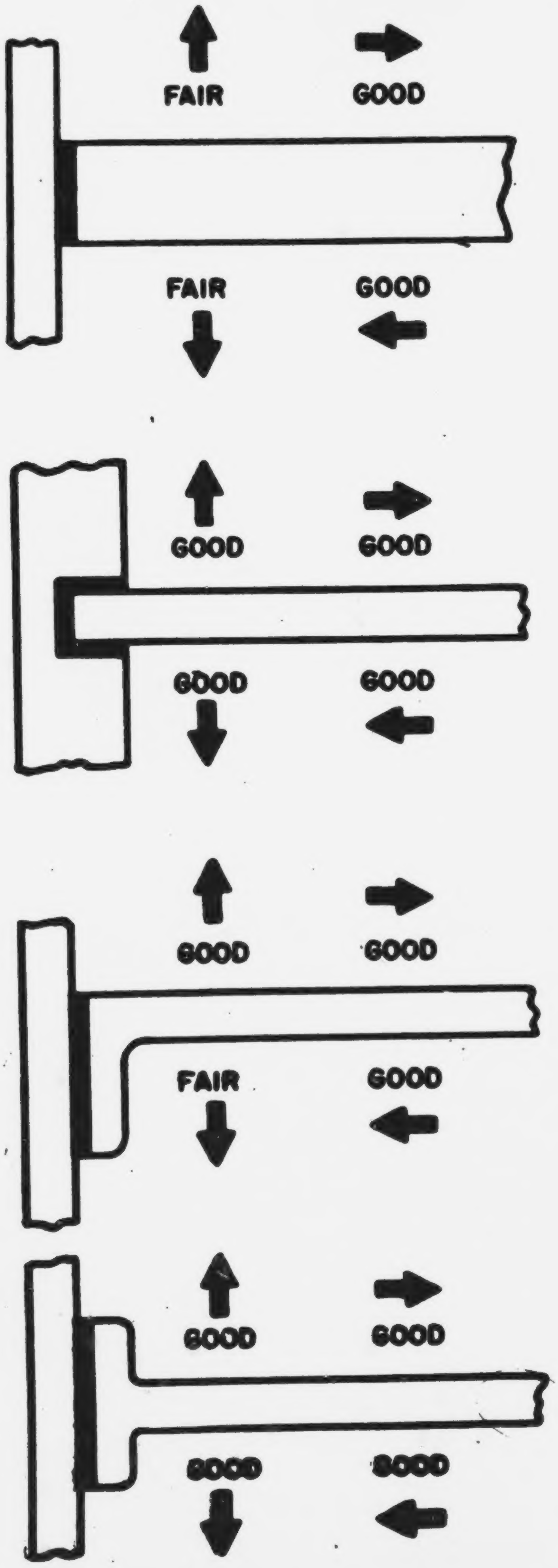

FAIR
GOOD
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Fig. 15. Joint stress evaluation.

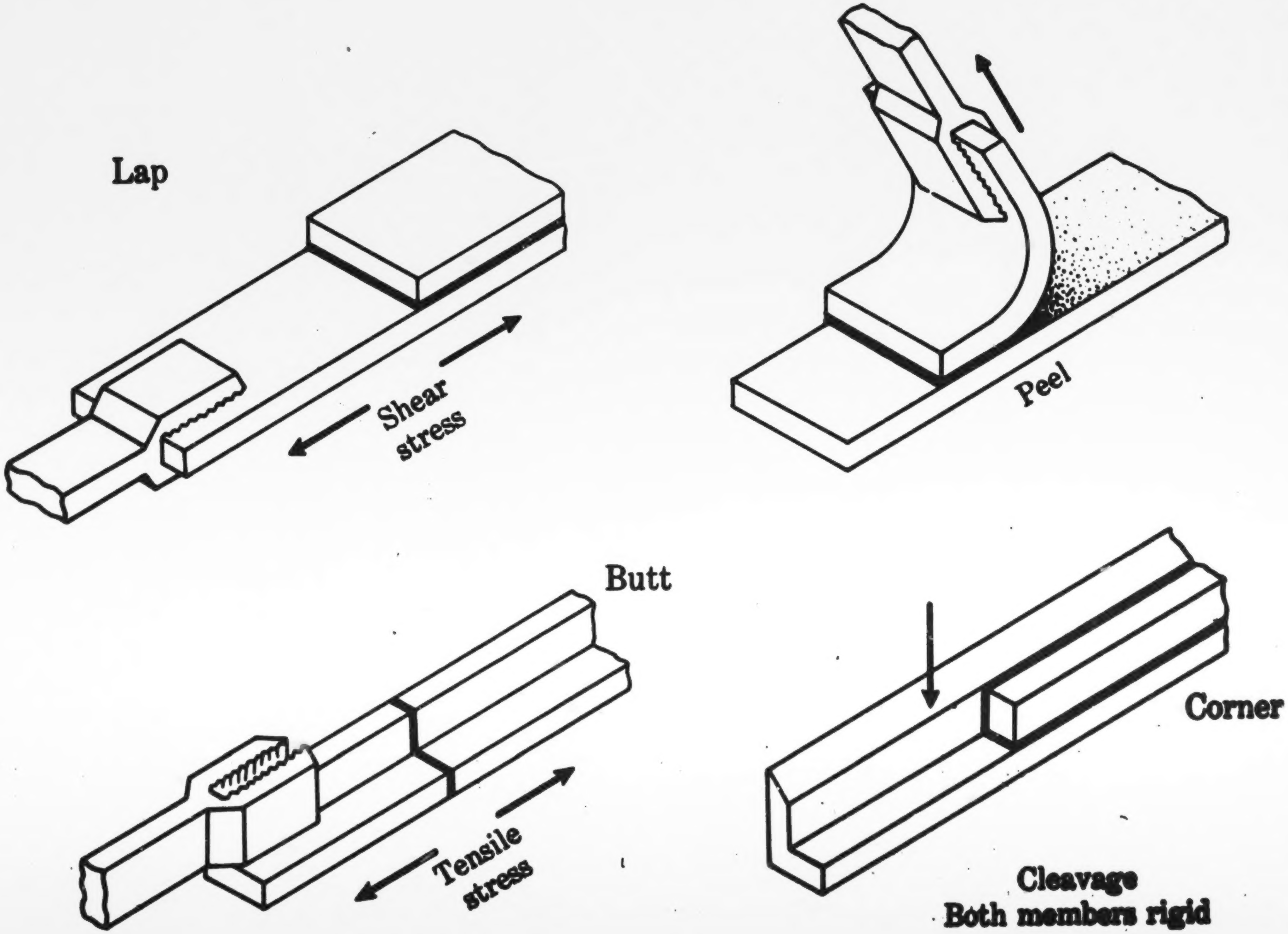

Lap
Shear stress
Peel
Butt
Tensile stress
Corner
Cleavage
Both members rigid

Fig. 15-8. Common types of joints and stresses used in adhesive applications.

mu—7

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Alfred J. Slowe
No. Attleboro High School
No. Attleboro, Mass.

INSTRUCTIONAL LEVEL: High School

PRESENTATION TIME: 2 hours

TITLE: Corrosion and Protection of Metals

INTRODUCTION:

The corrosion of metals is the destruction caused by the chemical or electrolyemical action of the surrounding environment. The metals become oxidized and products of the corrosion form.

Active investigation of the corrosion reactions of metals has led to methods of protecting metals against corrosion.

OBJECTIVES:

1. To acquaint the student with the various types of corrosion found in metals.
2. To promote an understanding of how corrosion may be prevented or reduced to metals.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:

Corrosion of metals occurs in many of the machined tools which are used in the other industrial arts area - as woodworking, plastics, etc.

The subject of chemistry is also concerned with corrosion since corrosion is caused by chemical processes.

USE IN INDUSTRY:

Modern technology requires metallic materials of high corrosion resistance, as well as improved methods of corrosion protection.

An intimate acquaintance with the fundamentals of corrosion science and methods of protection has become imperative for specialists in this field, for engineers, designers, and technicians who are concerned with metal technology, machine design, instrumentation, etc.

MATERIALS AND EQUIPMENT:
overhead projector
as many specimens of different types of metal corrosion as possible

EDUCATIONAL MEDIA:
transparencies - attached

UTILIZATION IN THE TEACHING LEARNING ENVIRONMENT:

PRESENTATION:

I. Introduction - trans. 1

II. Classification of Corrosion
   - A. Chemical Corrosion or Electrochemical Corrosion - trans. 2
      1. Chemical Corrosion - refers to cases of corrosion that are not accompanied by generation of electric current - ex: corrosion in nonelectrolytes or dry gases
         - a. Gaseous Corrosion - the complete absence of moisture on the surface - ex: corrosion of metals at elevated temperatures as the corrosion of furnace structures, internal combustion engines, steam and gas turbine blades, oxidation of metals on heating.
         - b. Corrosion in Nonelectrolytes - action by aggressive organic substances as alcohol, benzene, etc. that do not possess significant conductivity - ex: corrosion of Fe in S containing naphthas at elevated temperatures
      2. Electrochemical corrosion - refers to cases of corrosion with possible generation of current - corrosion of metals in electrolytes.
         - a. Corrosion in Electrolytes - caused by the action of natural waters and most aqueous solutions on metal structures - corrosion in total immersion, corrosion in partial immersion or waterline corrosion, corrosion in sea water, in acid, in salt or alkaline solutions.
         - b. Soil, Ground, or Underground Corrosion - refers to the action of a soil on a metal - ex: corrosion of pipelines installed underground and corrosion of foundations of high-voltage line poles.
         - c. Atmospheric Corrosion - occurs in the atmosphere and by moist gases. It is the most prevalent type of corrosion, because most metal structures are exposed to atmospheric conditions.

- d. Electrocorrosion or corrosion by an external current refers, for example to the corrosion of underground pipelines by stray currents.
- e. Contact Corrosion - caused by the contact of two or more metals of different electrochemical potentials.
- f. Stress Corrosion - caused by simultaneous action of the corrosive medium and mechanical stress. ex: corrosion under periodic load changes or corrosion fatigue - bridges, mine cables, shafts, high pressure tanks, often subject to this type.
- g. Corrosion with Simultaneous Action of Impingement or Abrasion - refers to corrosion due to impingement by a stream of water on ships propellers.
- h. Erosion Corrosion - occurs with simultaneous abrasive action by the corrosive mediums. ex: destruction of a propeller shaft journal is caused by friction of the bearing in contact with sea water
- i. Biocorrosion - refers to those cases of underground corrosion or corrosion in electrolytes that are sharply accelerated by products former by micro-organisms or as a result of their metabolism.

B. General or Local Corrosion

1. General or Surface Corrosion - trans. 3 - when corrosion extends over the entire surface of the metal
    - a. Uniform Corrosion - attack which is evenly distributed along the metal surface
    - b. Nonuniform Corrosion
    - c. Selective-structural Corrosion - process whereby a particular phase of a heterogeneous alloy is preferentially dissolved. ex: the dissolution of ferrite and the surface accumulation of carbides or graphite observed under some conditions in the corrosion of cast iron.
2. Local Corrosion - trans. 4 & 5
    - a. Strain Corrosion - initiated at isolated spots, and it spreads superficially, with the resultant coverage of relatively large areas
    - b. Pitting Corrosion - characterized by deep, local pits in limited areas
    - e. Pinpoint Corrosion - characterized by small pinpoint pits randomly distributed over the surface of the metal.
    - d. Subsurface Corrosion - begins on the surface but spreads mostly to the subsurface, often causes distention or stratification of the metal. ex:

blisters are observed occasionally on the surface of metals, either due to corrosion or to pickling of low quality rolled metal sheets.

e. Intercrystalline Corrosion - characterized by selective destruction of the metal at the grain boundaries. As a result of this, small external changes may be accompanied by serious loss of mechanical strength of the metal. In severe cases, the metal may completely disintegrate or pulverize.

f. Corrosion Cracking - rupture is determined by the direction of the greatest tensile stress. In this type of corrosion, cracking can extend not only through the grain boundaries but also can be transcrystalline.

III. Methods of Protecting Metals Against Corrosion

A. Treatment of the Medium in which Corrosion takes place:

1. Inhibitors - transparency 6 - special compounds which retard corrosion

a. Anodic Inhibitors - reduce the size of the anodic areas by coating them with insoluble compounds often with oxides as $NaNO_2$. A danger of anodic inhibitors is that if the amount used is insufficient to fully protect the anode surface, and only results in a reduction of the anodic area, the severity of the corrosion attack may even increase, since the same amount of action will be concentrated on a smaller active anode area.

b. Cathodic Inhibitors - a decrease in the intensity of the cathodic reaction always slows down corrosion, and therefore even an incomplete discontinuation of the cathodic reaction is considered beneficial. ex: $ZnSO_4$

c. Mixed Inhibitors - which affect both the cathodic and the anodic reaction. ex: potassium dichromate or chromate. If the influence of the cathodic reaction is greater than that of the anodic, the inhibitor can be classified as harmless; the reverse of this would be on the dangerous side.

B. Electrochemical Protection

1. This method of protection is accomplished by either joining a metal of more negative potential (sacrificial anode) to the structure, or by means of an externally imposed current.

Example 1: trans. 7 & 8 - method of attachment of a zinc protector to a steel wall, In this electrochemical method of protection, a metal of more negative potential (sacrificial anode) is added to the structure. In this example, a piece of zinc is attached to the articles to be protected, making direct contact with them. An artificial galvanic cell is thus created, the added zinc electrode is the anode which is destroyed, the article to be protected then becomes cathodic.

Example 2: Trans. 9 - This method of protection is accomplished by means of an externally imposed current, a DC source as a dynamo, accumulator, or battery as well as an additional electrode to serve as the anode. The articles to be protected are connected to the negative terminal of the current source and are thereby cathodically polarized. The additional electrode which is connected to the positive pole is anodically polarized.

This method of protection can only be used in solutions of good electrical conductivity as sea water or neutral salt solutions. In solutions which have good electrical conductivity but in which the sacrificial anode corrodes rapidly, this method of protection is uneconomical.

C. Protective Coatings - trans 10 & 11

1. The role of coating is to insulate the metal from the external medium, and thus prevent the formation of microcells on the metal surface.

   The amount of protection against corrosion depends upon the thickness of the zinc coating. The heavier the coating the longer the time before first rusting of the bare metal will occur.

   a. Hot Dipping - trans. 12 - most widely used method. In this process the components to be coated are immersed in a bath of the molten metal for a short period of time.

      The main conditions necessary for successful coating by hot dipping are:

      1) the molten metal must wet the surface of the articles to be protected and coat it evenly
      2) mutual alloying between basis metal and coating must take place
      3) the coating metal must have a lower melting point than the articles to be coated

   b. Galvanizing - trans 13. A coating of zinc will protect iron electrochemically against corrosion in the atmosphere, in water and in a number of neutral salt solutions.

1) Used to form coatings on pipes, containers, machine components, steel sheet, wire, etc.
2) Components are pretreated chemically, treated with a flux and then immersed in a molten zinc bath.
   Due to diffusion of zinc into the iron and some dissolution of the iron in the zinc, an iron-zinc alloy coating forms on the surface of the components consisting of several layers, each of different composition (refer to trans.)

c. Cementation Process - trans 14
Diffusion coatings are applied by heating the components to be protected together with the coating metal, in the form of a powder at a definite temperature. This process may also be carried out by heating the components in an atmosphere of volatile compounds of the coating metal. The protective layer obtained in this manner consists of an alloy between iron and the coating metal.

1) Sheradizing - trans. 15
   a) widely used for producing coatings on small hardware articles and electrical components
   b) after cleaning by sand blasting, the articles are loaded into drums together with zinc powder and zinc oxide. The drum is slowly heated in the furnace to 440° and kept at that temperature for 2 - 4 hours.
2) Calorizing - trans 16 - process of saturating the surface layer of steel, iron or copper with aluminum by means of diffusion. Articles are placed in a refractory box with a calorizing mixture and the box hermetically sealed and heated in a reverbatory furnace to 900-1000° causing diffusion of aluminum into the basis metal. Optimum calorizing mixture: 49% Fe-Al alloy (40-50% Fe) in powder form, 2% NH_4Cl
3) Chromizing - trans 17 - similar process to calorizing. Saturation of a common carbon steel with chromium increases its high temperature oxidation resistance, hardness and wear resistance.

4) Siliconizing - trans 18 - addition of silicon to normal carbon steel raises the high temperature oxidation resistance of the metals at temperatures up to 850°, as well as corrosion resistance in a number of acids as nitric and hydrochloric. The main constituents of the mixture used are: powdered silicon carbide and refractory clay to prevent sintering. Carried out at temperatures of 1100° for 10 - 24 hours.

d. Electroplating - trans. 19 - at the negative electrode, electrons leave the electrode and enter the solution. At the other end of the reaction, electrons leave the solution and enter the positive electrode.Use of electrochemical series

e. Spraying - trans 20 - coating with sprayed molten metal .

1) zinc, cadmium, lead, aluminum, tin, nickel, copper, bronze, high carbon steel

2) purpose:

a) to protect metals from action of corrosive media

b) imparting decorative and other specific properties to the components

c) for repairing eroded surfaces

d) to correct rejects due to faulty machining and rectifying defects in expensive castings

3) Firmness of attachment of the coating to the surface of the treated components depends on:

a) Size of the droplets of sprayed metals

b) velocity of flight

c) degree of deformation they undergo on impinging upon the work

f. Cladding - process of mechanically coating one metal with another

1) common bimetals - trans. 21

a) steel-copper in form of sheet, strip, or wire used in electrical, defence, machine construction, paper, and textile industries

b) steel-brass and steel-tombac for manufacturing of medical and laboratory apparatus

c) steel-nickel used in machinery for the food and soap industries

d) steel-stainless steel - less expensive

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Obtained by written testing, participation in classroom discussion, and lab work.

UNIT EVALUATION:

The unit will be evaluated in terms of the objectives by a composite of individual student performance and observation by the teacher of student interest.

DEFINITION OF TERMS:

see attached handout

REFERENCES:

STUDENT:

G. T. Bakhvalov & A. V. Turkovskaya, *Corrosion and Protection of Metals*

TEACHER

B. H. Tytell, I. Geld, H. S. Preiser, *Theory of Corrosion and Protection of Metals*

MATERIALS LAB. 114

METAL CORROSION

A chemical or electrochemical action which will gradually convert the basic metal into an oxide, salt, or some other compound thereby destroying its strength, ductility, and other desirable mechanical properties that metal possesses.

Some of the typical chemical reactions are as follows:
(From "Materials of Engineering" by Carl Keyser)

1. Combinations of metals with nonmetals, in which water does not take part, such as:

   $$Me + Nm \longrightarrow MeNm$$

   where Me is a metallic element,and Nm is a nonmetallic substance. A specific example of corrosion in which this kind of reaction occurs is the high-temperature oxidation of iron or steel in dry air:

   $$2Fe + O_2 \longrightarrow 2FeO$$

   It is also possible to form Fe_2O_3 as the corrosion product.

2. Combinations of metals with oxygen, in which water is necessary for the reaction to proceed, such as:

   $$Me + 1/2O_2 + H_2O \longrightarrow Me\,(OH)_2$$

   where Me is a suitable metallic element. Probably the most important specific example of this reaction is the rusting of steel under ordinary atmospheric conditions:

   $$Fe + 1/2O_2 + H_2O \longrightarrow Fe\,(OH)_2$$

   In dry air at room temperature, iron and steel will not rust. In moist air the iron hydroxide which is formed (it may be $Fe\,(OH)_2$ or $Fe\,(OH)_3$) frequently decomposes to the appropriate oxide (FeO or Fe_2O_3), accompanied by loss of moisture:

   $$Fe\,(OH)_2 \longrightarrow FeO + H_2O$$

   so that the net reaction is:

   $$Fe + 1/2O_2 \xrightarrow{H_2O} FeO$$

3. Displacement of hydrogen from acids or acid solutions:

   $$Me + H_2SO_4 \longrightarrow MeSO_4 + H_2$$

An example of corrosion involving this reaction is the attack of iron by sulfuric acid, or the tarnishing of silver by hydrogen sulfide in the presence of moisture:

$$Ag + H_2S \xrightarrow{H_2O} AgS + H_2$$

4. Displacement of hydrogen from water which usually contains small amounts of dissolved inorganic substances:

$$Me + 2H_2O \longrightarrow Me(OH)_2 + H_2$$

Frequently oxygen dissolves in the water and combines with the liberated hydrogen:

$$H_2 + 1/2O_2 \longrightarrow H_2O$$

The reaction can also be written:

$$Me \text{ ——— } Me^{++} + 2e$$

$$2H_2O + 2e \longrightarrow 2OH + H_2$$

The rusting of iron in water is a form of corrosion involving this reaction.

5. Displacement by one metal of the ions of another metal from a salt solution:

$$Me' + MeSO_4 \longrightarrow Me'SO_4 + Me$$

If iron is immerged in a solution of copper sulfate, copper will plate out the iron and the iron will go into solution.

WHAT WE DO AND DON'T KNOW ABOUT CORROSION

What We Do Know	What We Don't Know
Electrochemical Theory	
Presence of anodes and cathodes on corroding surfaces. Relation between current flow and corrosion. Effects of polarization and resistance current flow.	Mechanism by which a metal atom leaves its lattice and becomes a hydrated ion in solution. Nature and extent of overvoltage factors (i.e., oxygen reduction and hydrogen evolution overvoltages) which influence the behavior of metal surfaces when they are acting as cathodes.
Stress Corrosion	
Some of the metals and environments where stress corrosion can be expected, e.g., brass in ammonia, steel in caustic, and stainless steels in chlorides.	The mechanism of stress corrosion cracking in most systems, especially when the cracks are transcrystalline and there is no definable path along which corrosion and cracking might be expected to develop. Some present theories are: (1) an anodic boundary phase, as in aluminum alloys; (2) stress-induced pr-cipitation of corrodible phases, e.g., nitrides in steels or martensite in austenitic steels; (3) rupturing of protective films by plastic deformation which allows development of anodic surfaces at tips of advancing cracks. Role of hydrogen in stress corrosion cracking, and why presence of hydrogen sulfide in such a potent stimulator of hydrogen embrittlement. What distinguishes an environment that causes cracking from one that does not? Why some environments cause intercrystalline cracking while other very similar environments cause transcrystalline cracking.
Pitting	
Electrochemical aspects of pit propagation. Physical circumstances that favor pitting.	Why a pit starts at one point rather than another. Why some ions such as chloride ions are more active than others in starting pitting. The mechanisms by which some alloying elements, such as molybdenum, improve resistance to pitting.

What We Do Know	What We Don't Know
Impingement Attack	
Relative merits of different alloys in resisting impingement attack. Probable mechanisms that are involved.	What determines the ability of an alloy to form an adherent protective film. What determines the protective film repair rate. How aluminum improves protective films on brass, and iron improves protective films on cupro-nickels.
Cavitation Erosion	
In a general way, the circumstances under which cavitation damage may occur. Relative merits of different alloys in resisting cavitation erosion. How to solve some problems by changing design or by controlling corrosivity of environment, as with inhibitors.	Exact mechanism of cavitation damage. Relative importance of mechanical and chemical factors. Mechanism by which cathodic currents reduce cavitation damage. How to make an accelerated test that will rate materials properly.
Cathodic Protection	
How to protect metals in some applications, e.g., underground pipes and ship hulls. How to monitor cathodic protection by potential measurements.	Exact mechanism by which cathodic protection is achieved. Significance of potential measurements used to monitor cathodic protection.
Atmospheric Corrosion	
That there is a great spread in corrosivities of atmospheres at different locations and that this spread is due largely to atmospheric pollution. How to measure pollution, humidity, temperatures, etc., quantitatively.	How to use measurements of pollution and other factors to estimate the probable corrosivity of a particular atmosphere.

From "Materials," 1963.

CORROSION TERMS YOU SHOULD KNOW

1. Active potential - An electric potential associated with the condition of corrosion, as contrasted with a condition of passivity.

2. Anion - A negatively charged ion or radical which migrates toward the anode under the influence of a potential gradient.

3. Anode - An electrode or portion of an electrode at which a net oxidation reaction occurs.

4. Anodic protection - The reduction or elimination of corrosion that can sometimes be obtained by making current flow from it to the solution, as by connecting it to the positive pole of a source of current. Under most conditions, as the potential of an initially active metal is gradually shifted in a more noble direction (as by potentiostatic means) the corrosion current gradually increases. However, with suitable combinations of metal and solution, a critical potential is soon reached. At somewhat higher values of the potential the current drops to a very low value, and the metal becomes passive. (See also Cathodic Protection.)

5. Cathode - An electrode or portion of an electrode at which a net reduction reaction occurs.

6. Cathodic corrosion - An increase in corrosion of a metal caused by making it cathodic.

7. Cathodic protection - Reduction or prevention of corrosion of a metal surface caused by making it cathodic; e.g., by using a sacrificial anode or impressed current. (See also Anodic Protection)

8. Cation - A positively charged ion or radical which migrates toward the cathode under the influence of a potential gradient.

9. Cavitation damage - Deterioration caused by the formation and collapse of cavities in a liquid.

10. Cell - A source of electric current responsible for corrosion. It consists of an anode and a cathode immersed in a electrolyte. The anode and cathode may be separate metals or dissimilar areas on the same metals. When the electrodes are in electrical contact with each other, they develop a difference in potential which causes current to flow and produces corrosion at the anode. A cell involving an electrolyte in the corrosion process is referred to as an electrolytic cell.

11. Concentration cell - An electrolytic cell, the emf of which results from differences in the composition of the electrolyte at anode and cathode areas.

12. Corrosion fatigue limit - The maximum stress that a metal withstands without failing when cyclically stressed under corrosive conditions.

13. Crevice corrosion - Localized corrosion resulting from the crevices that are formed between a metal and a nonmetal, or between two metal surfaces.

14. Critical humidity - The value of relative humidity above which the atmospheric corrosion of a metal increases sharply.

15. **Dezincification** - A corrosion phenomenon resulting in parting of zinc from copper-zinc alloys.

16. **Electrolyte** - An ionic conductor.

17. **Fretting** - Deterioration resulting from repetitive slip at the interface of two materials. If this deterioration is increased by corrosion, it is referred to as fretting corrosion.

18. **Galvanic series** - A list of metals and alloys arranged according to their relative potentials in a given environment.

19. **Galvanic corrosion** - Corrosion associated with the current of a galvanic cell made up of dissimilar electrodes. Also known as a couple reaction.

20. **Graphitic corrosion** - Corrosion of gray cast iron in which the metal constituents are converted to corrosion products and the graphite is left intact.

21. **Intergranular corrosion** - Corrosion that occurs preferentially at grain boundaries.

22. **Ion** - An electrically charged atom or radical.

23. **Noble metal** - A metal which in nature commonly occurs in the free state. Also, a metal or alloy whose corrosion products are formed with a low negative or positive free energy change.

24. **Oxygen concentration cell** - A galvanic cell caused primarily from differences in oxygen concentration.

25. **pH** - The relative acidity of a solution as determined by the concentration of hydrogen ions. It is defined by the equation: $pH = \log_{10} (1/a_h+)$, where $a_h + =$ hydrogen ion activity = the molal concentration of hydrogen multiplied by the mean ion activity coefficient.

26. **Protective potential** - A term used in cathodic protection to describe the potential as measured against an appropriate half-cell at which all anodic corrosion reactions can be assumed to be eliminated and protection provided for the materials.

27. **Spalling** - Spontaneous separation of a surface layer from a metal.

28. **Stray current corrosion** - Corrosion caused by corrosion through paths other than the normal circuit or by extraneous current in the earth.

29. **Stress corrosion cracking** - Spontaneous cracking produced by the combined action of corrosion and static stress (residual or applied).

30. **Tuberculation** - The formation of localized corrosion products which are scattered over the surface in the form of knoblike mounds.

31. **Underfilm corrosion** - Corrosion that occurs under films in the form of randomly distributed hairlines (also known as filiform corrosion).

Taken from "Materials in Design Engineering," January 1963

CORROSION

CLASSIFICATIONS OF CORROSION

CHEMICAL

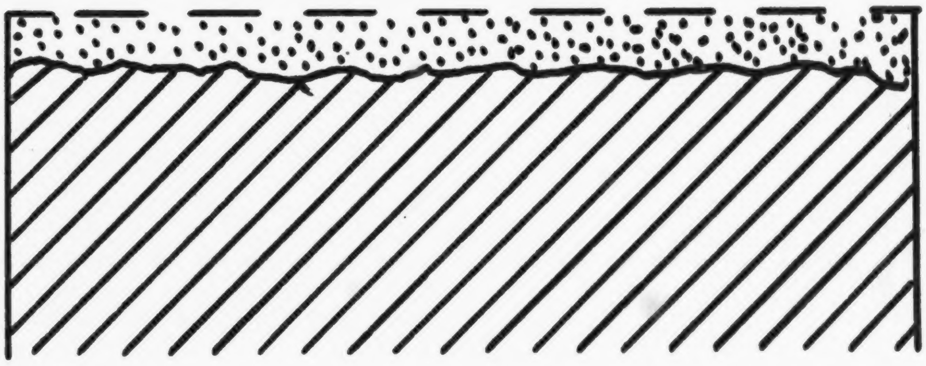
1. Gaseous Corrosion
2. Corrosion in non-electrolytes

ELECTROCHEMICAL

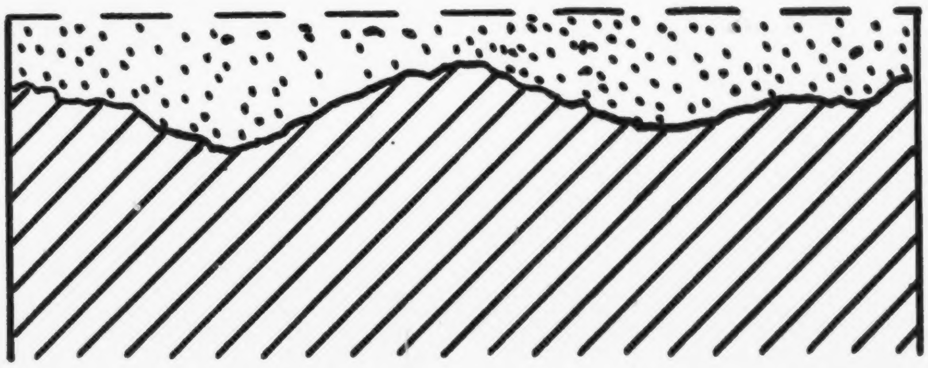
1. corrosion in electrolytes
2. soil, ground, or underground corrosion
3. atmospheric corrosion
4. electrocorrosion
5. contact corrosion
6. stress corrosion
7. corrosion WITH simutaneous action OF IMPINGEMENT
8. erosion corrosion
9. biocorrosion

I.

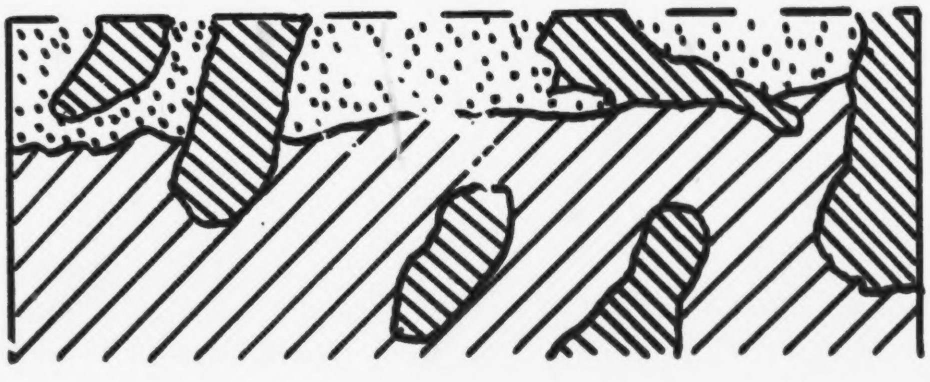
General Corrosion



Uniform Corrosion



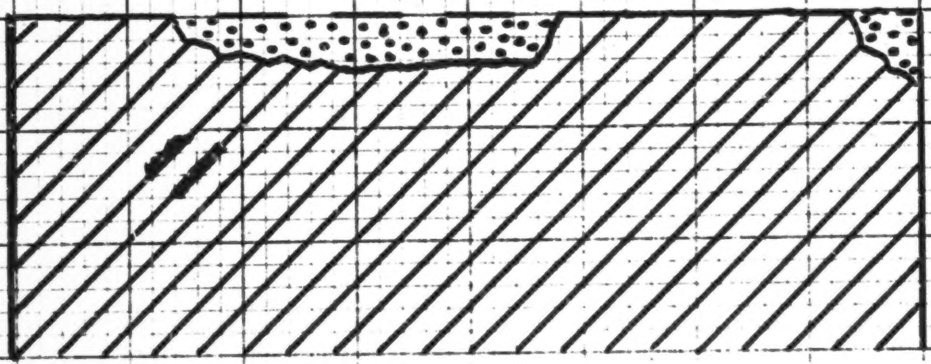
Nonuniform Corrosion



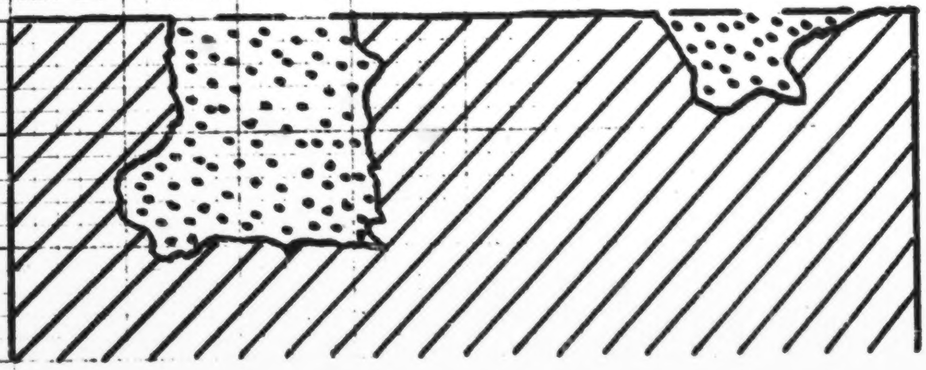
Selective-Structural Corrosion

II.

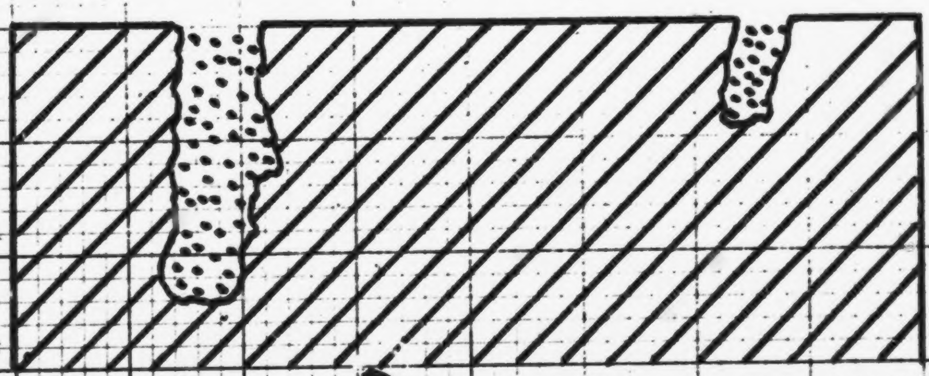
Local Corrosion



Stain Corrosion



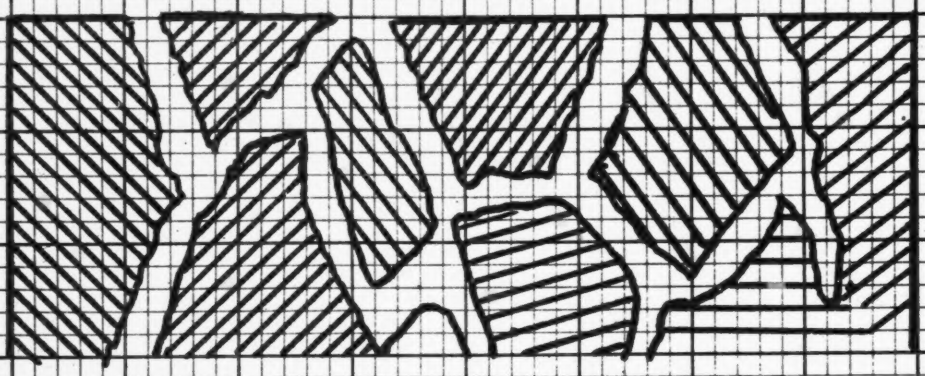
Pitting Corrosion



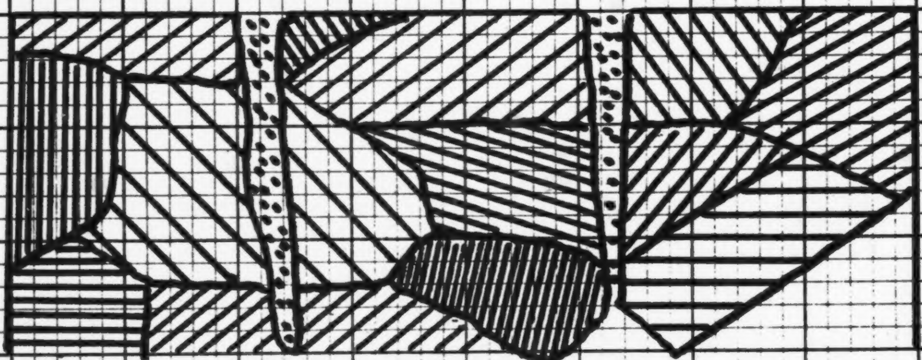
Pinpoint Corrosion

II.

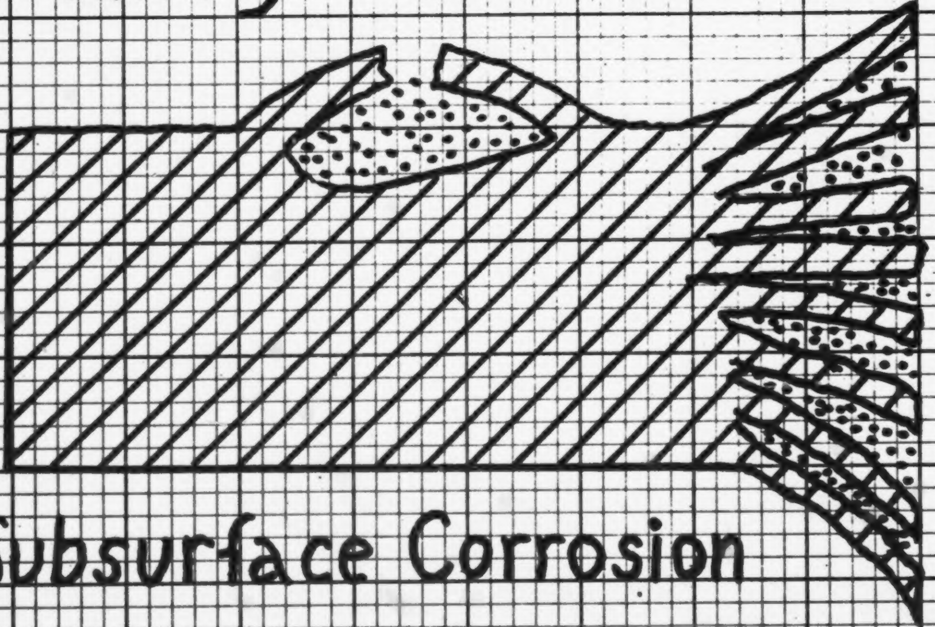
Local Corrosion



Intercrystalline Corrosion



Transcrystalline Corrosion

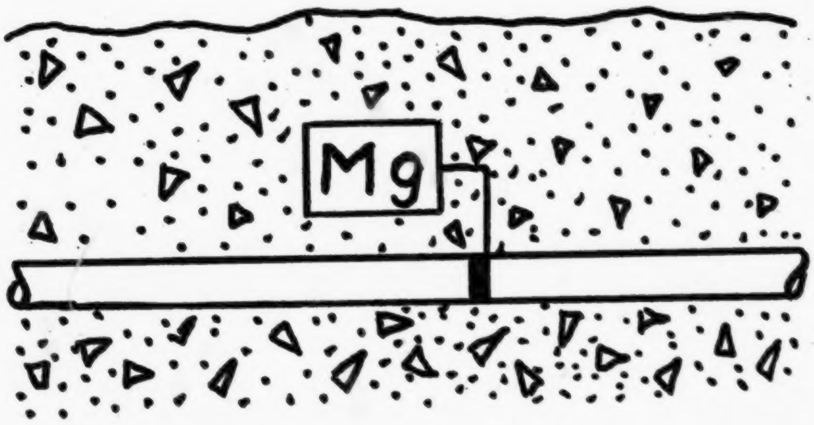


Subsurface Corrosion

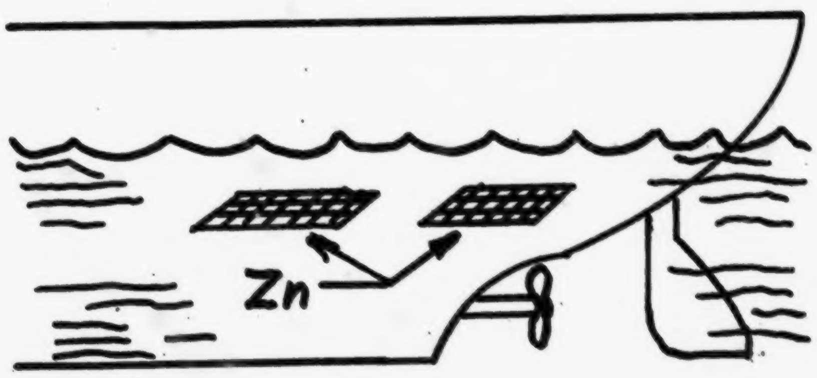
INHIBITORS

1. Anodic
2. Cathodic
3. Mixed

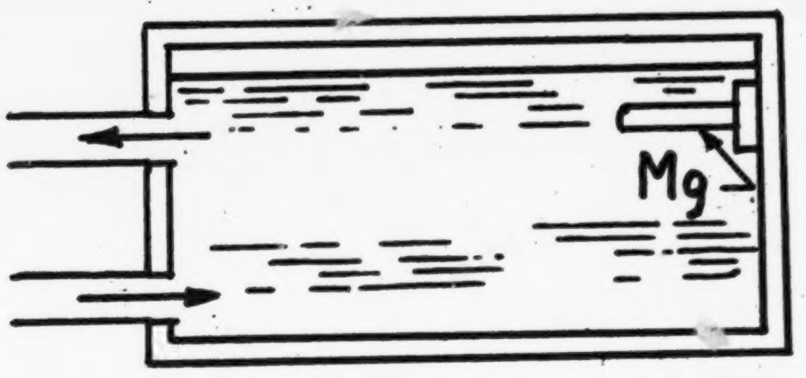
Sacrificial Anodes



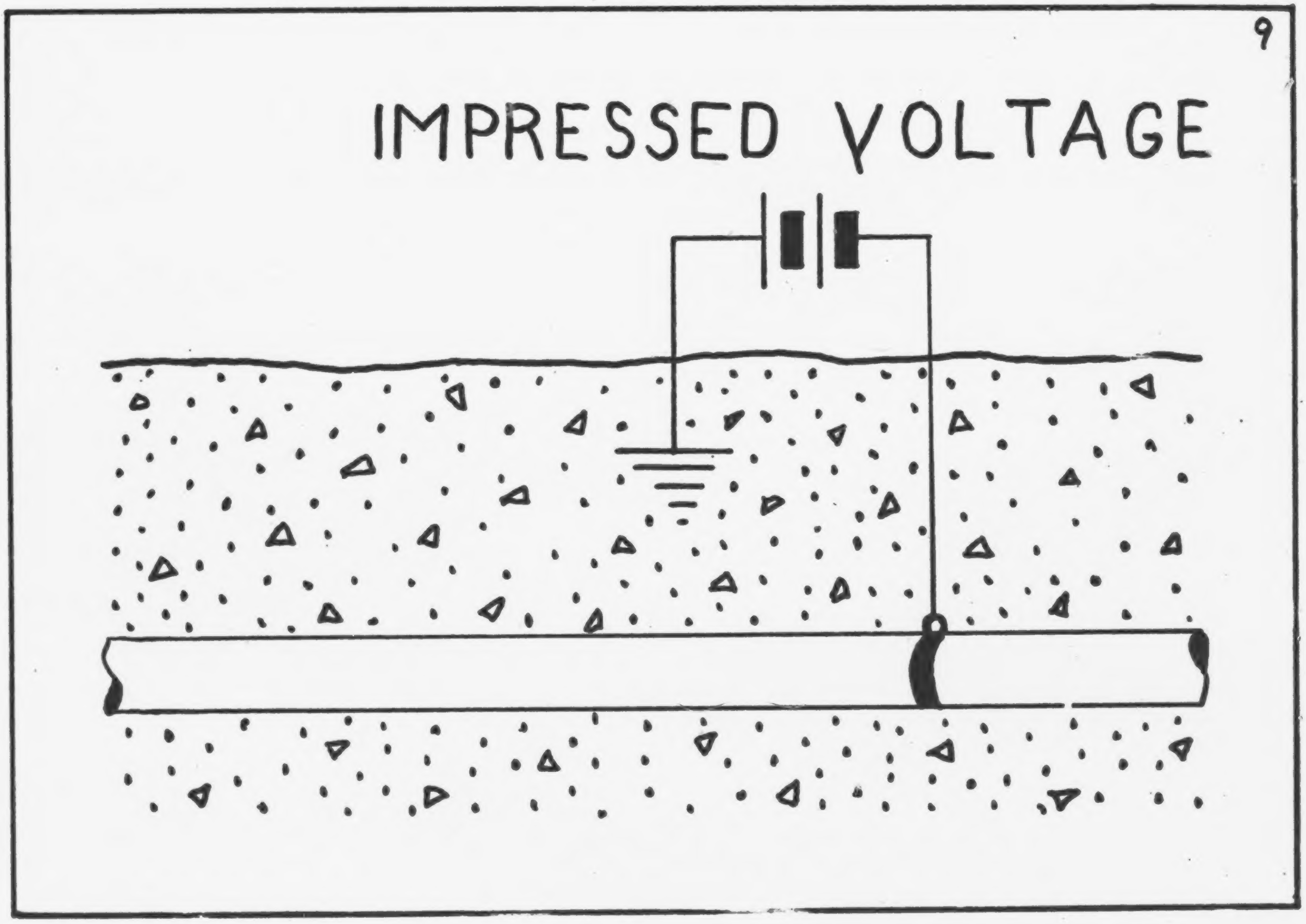
Buried Mg plates along a pipeline



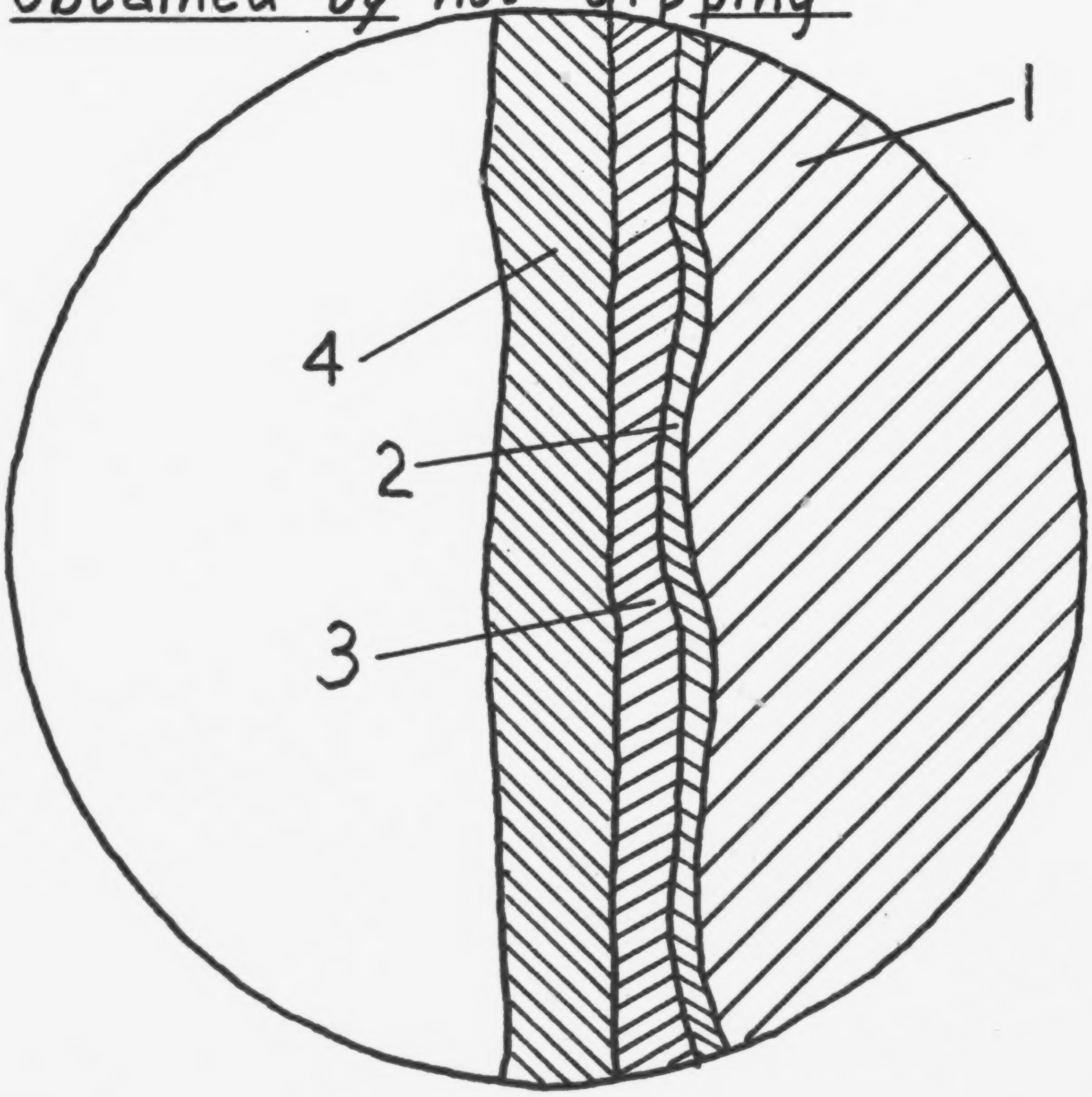
Zinc plates on ship hulls



Mg bar in an industrial hot water tank

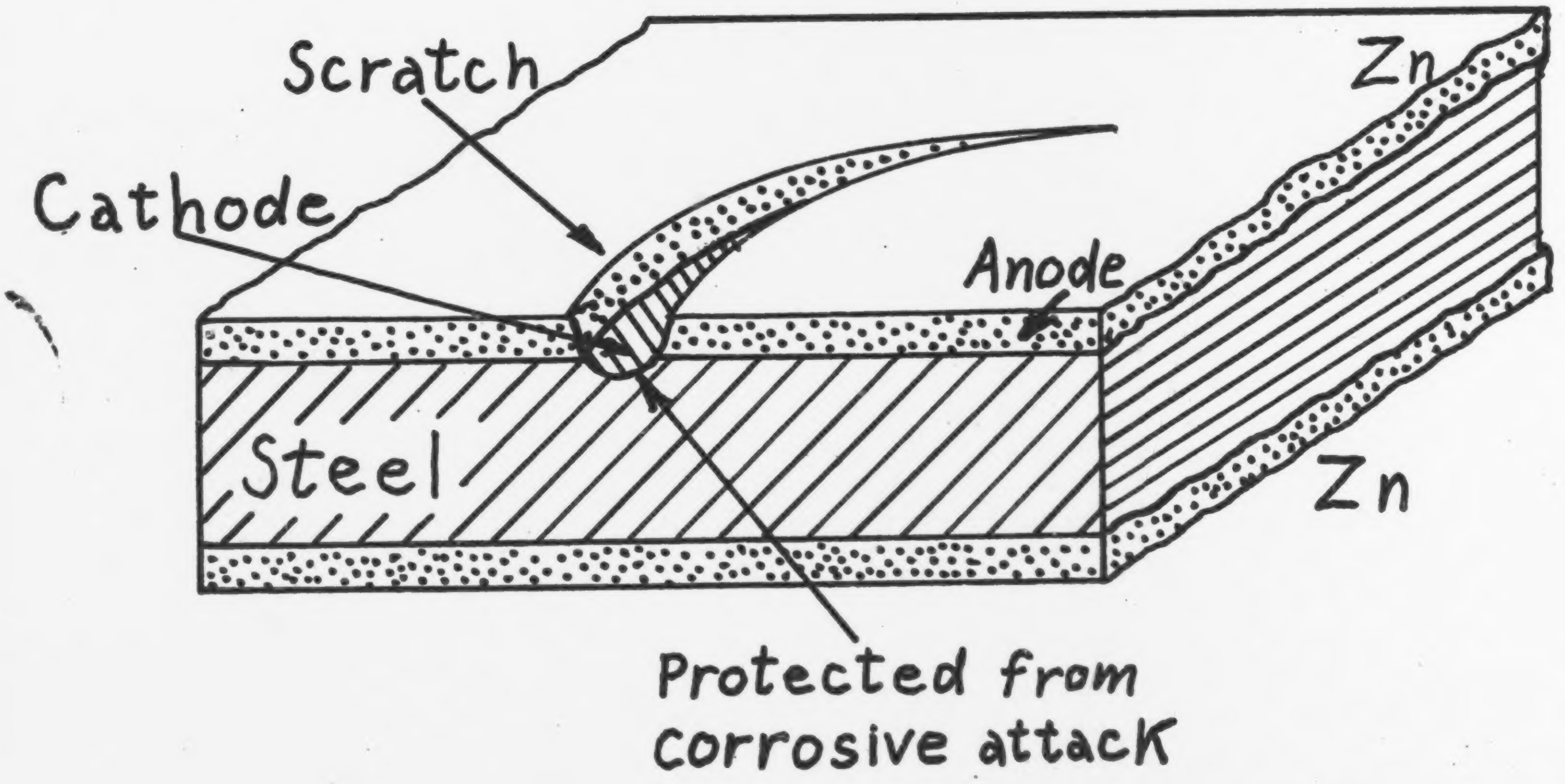

9
IMPRESSED VOLTAGE

Schematic drawing of the structure of a zinc coating, obtained by hot dipping

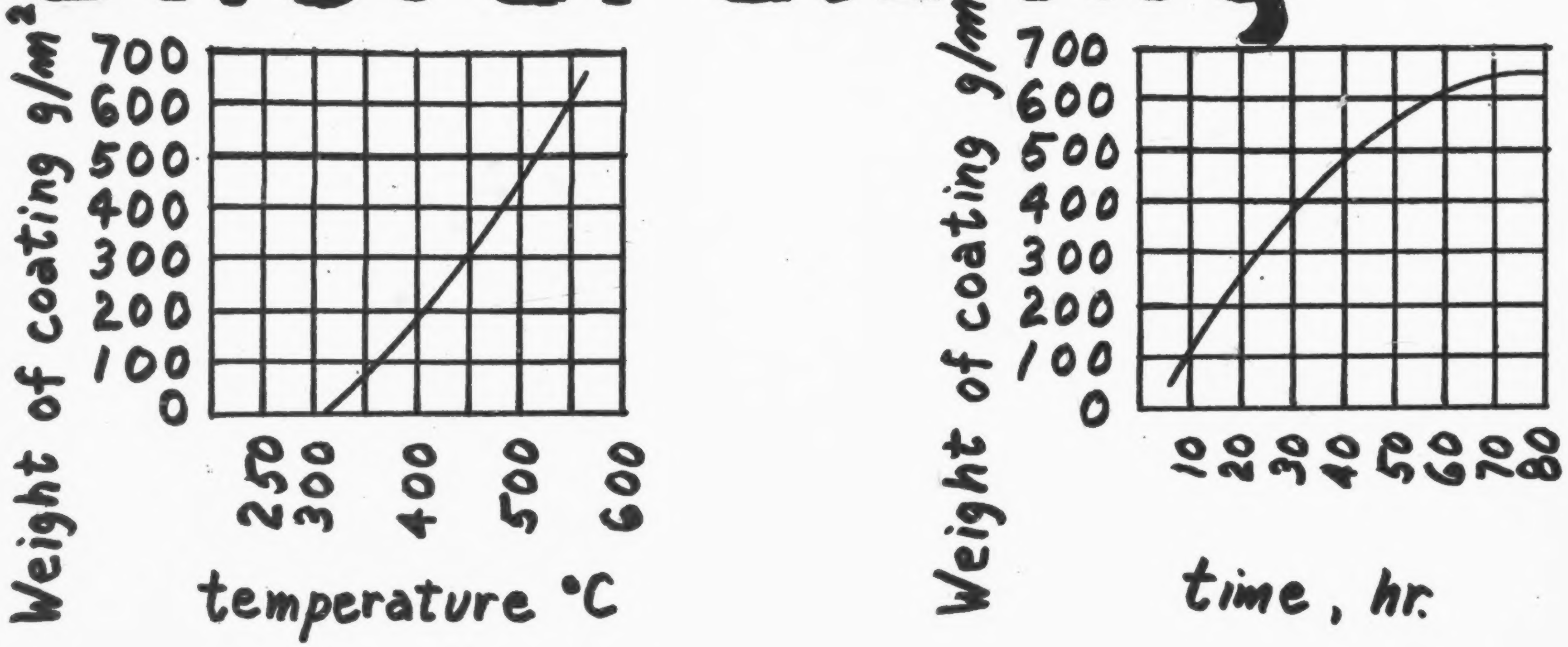


1 — iron; 2 — layer of iron-zinc alloy rich in iron; 3 — layer of iron-zinc alloy rich in zinc; 4 — zinc

Galvanized Steel
(CROSS SECTION)

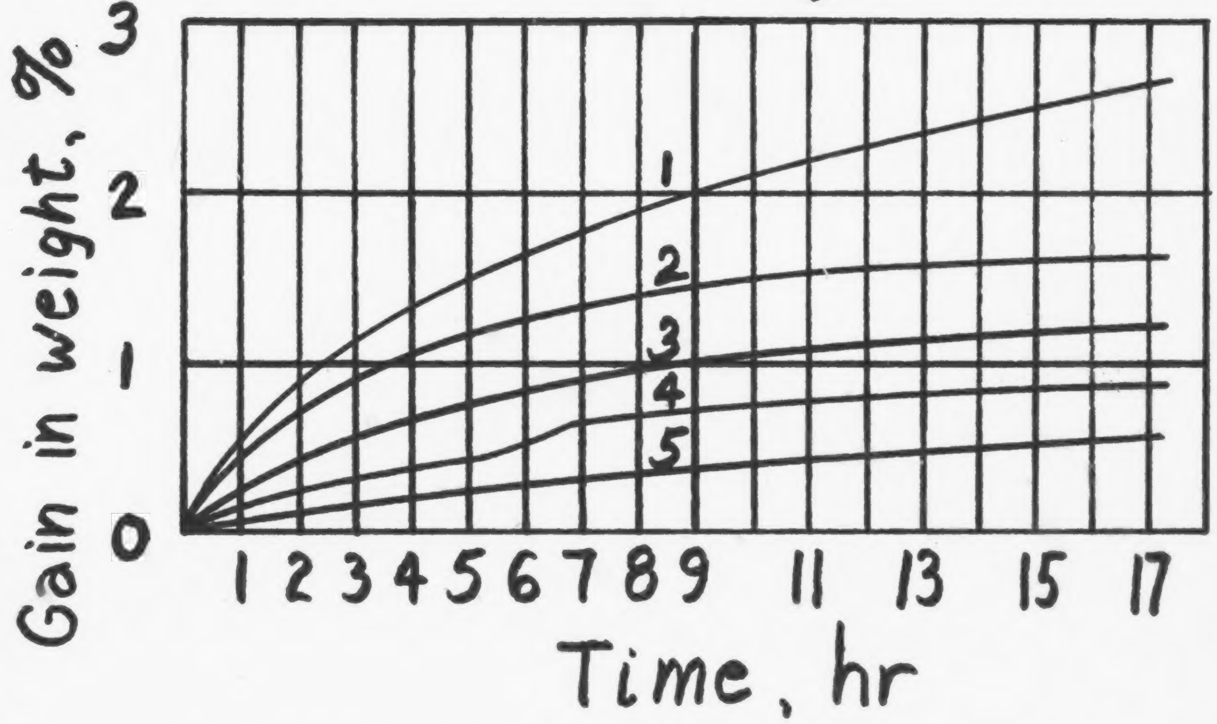

Scratch
Cathode
Anode
Zn
Steel
Zn
Protected from corrosive attack

Sherardizing



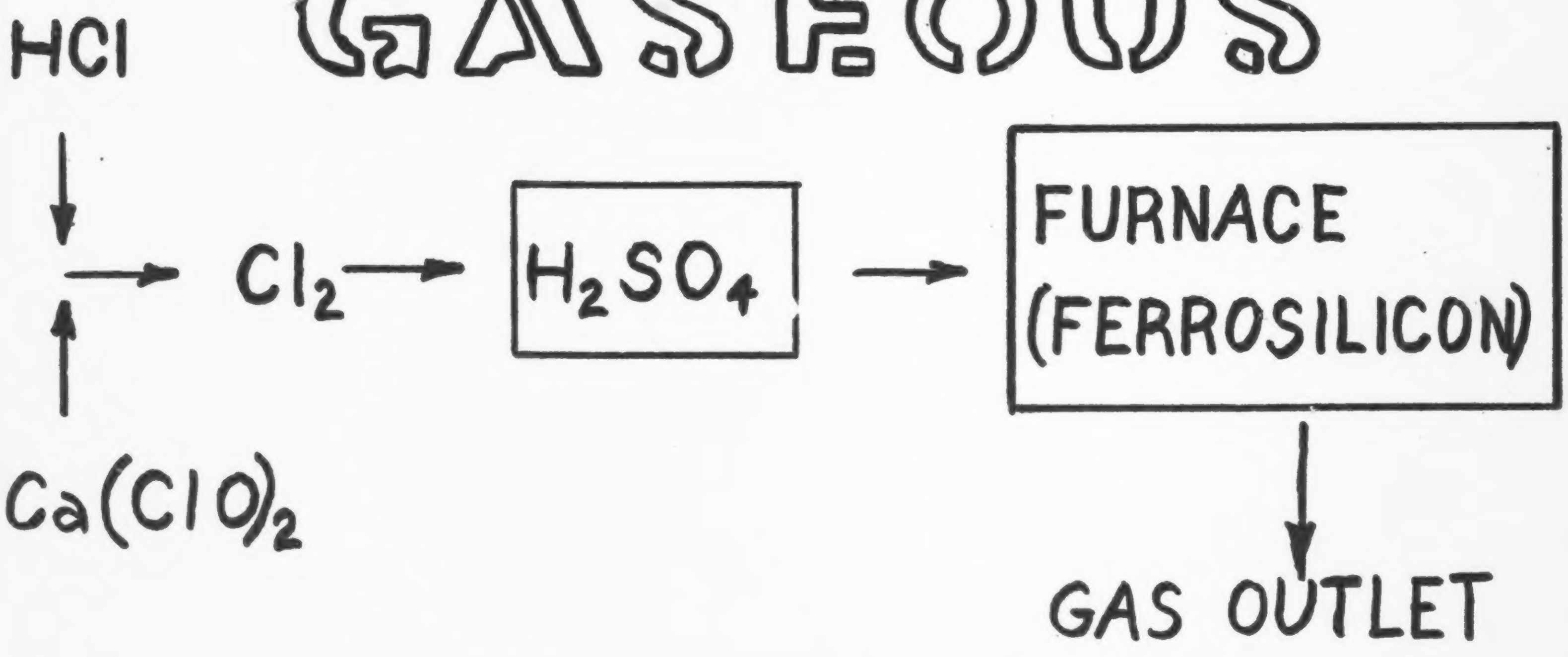
Dependence of the thickness of a zinc coating on (a) temperature and (b) time of holding in furnace

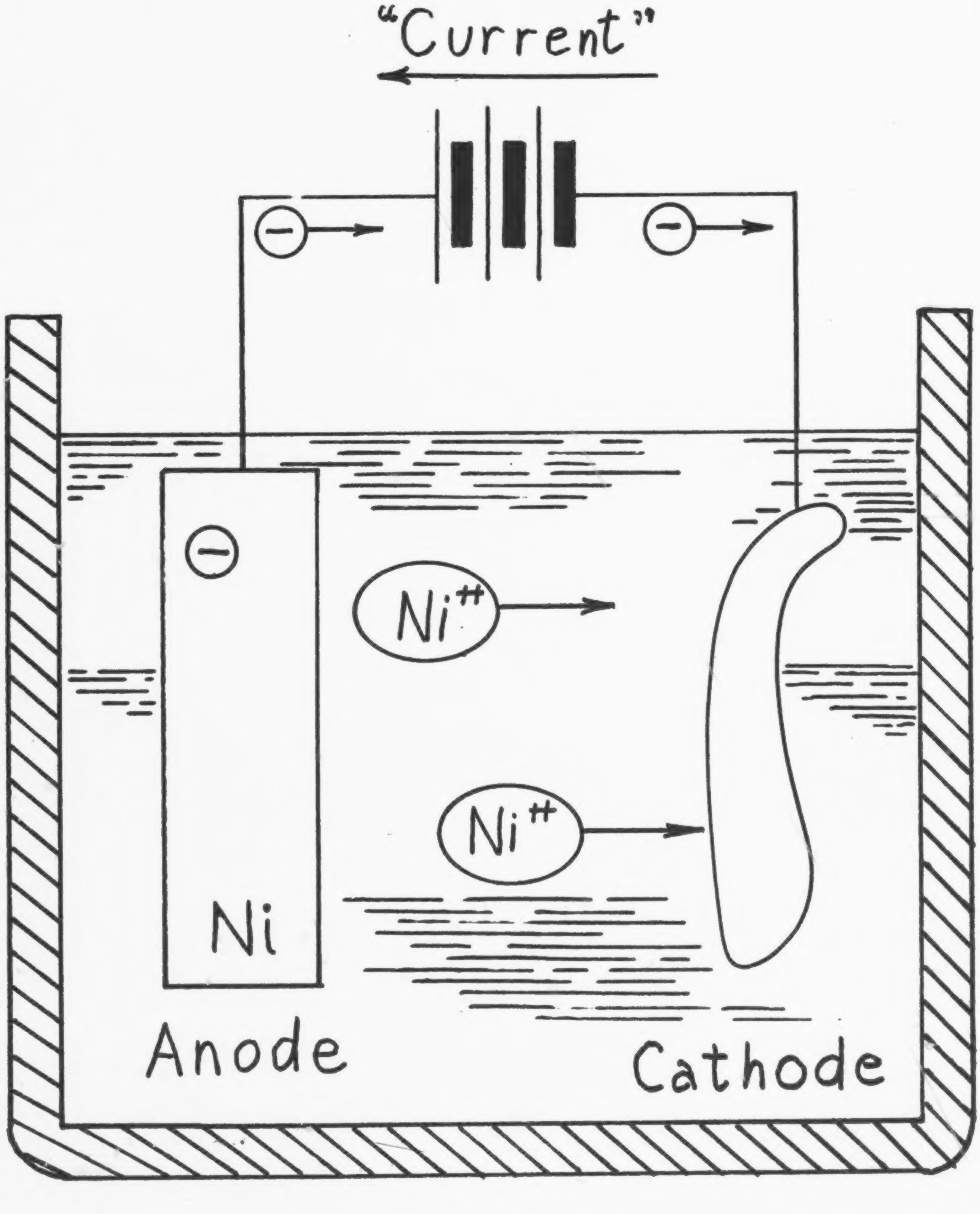
High-temperature Oxidation Resistance of Chromized Steel



1– steel 10, not chromized; same
steel, chromized at 980° for 2 hr;
3– same steel chromized for 4 hr;
4– same steel chromized for 10 hr;
5– stainless steel EZh-1.

GASEOUS SILICONIZING


HCl
Cl_2
H_2SO_4
FURNACE
(FERROSILICON)
$Ca(ClO)_2$
GAS OUTLET


"Current"
Ni++
Ni++
Ni
Anode
Cathode

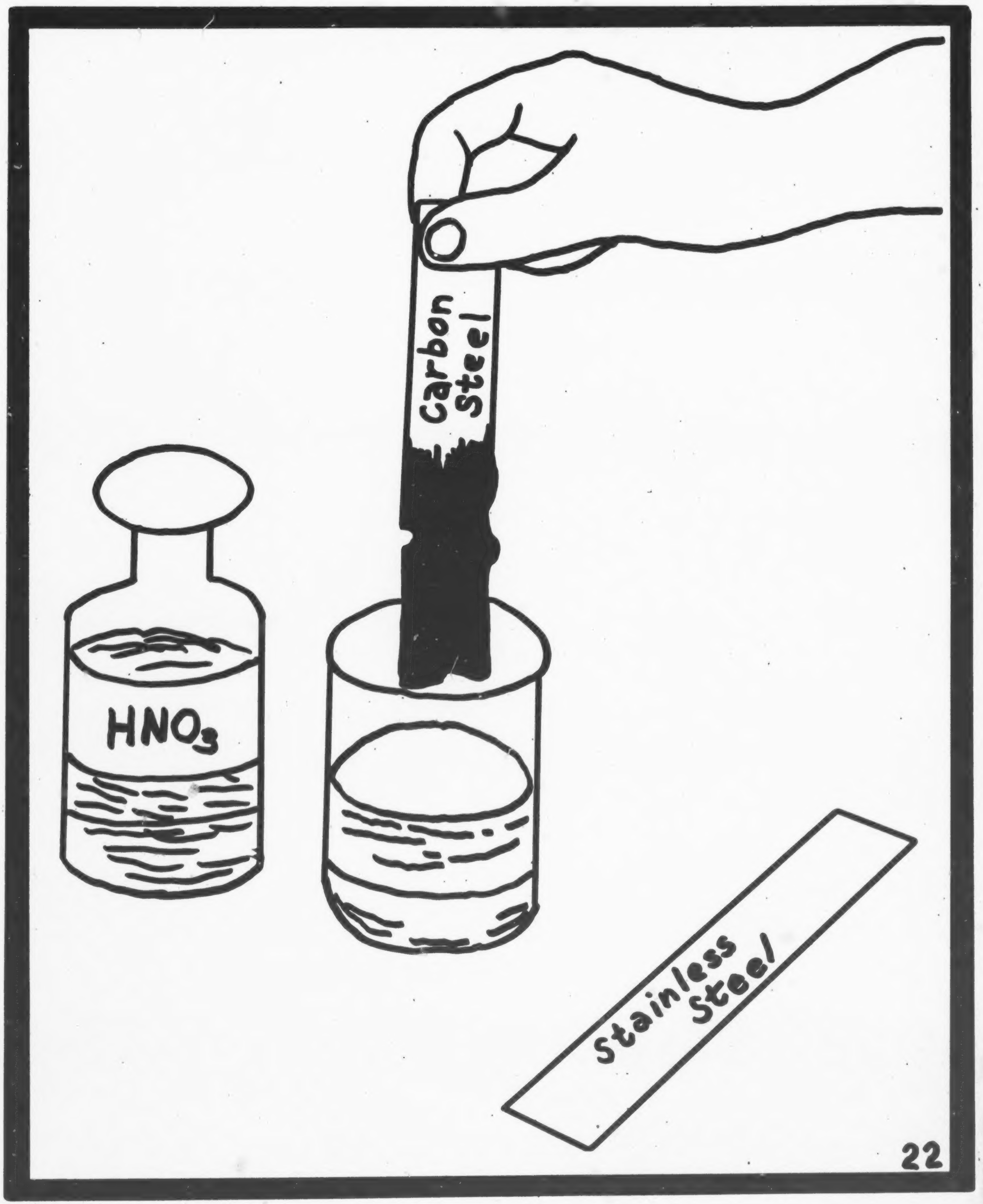
Electroplating

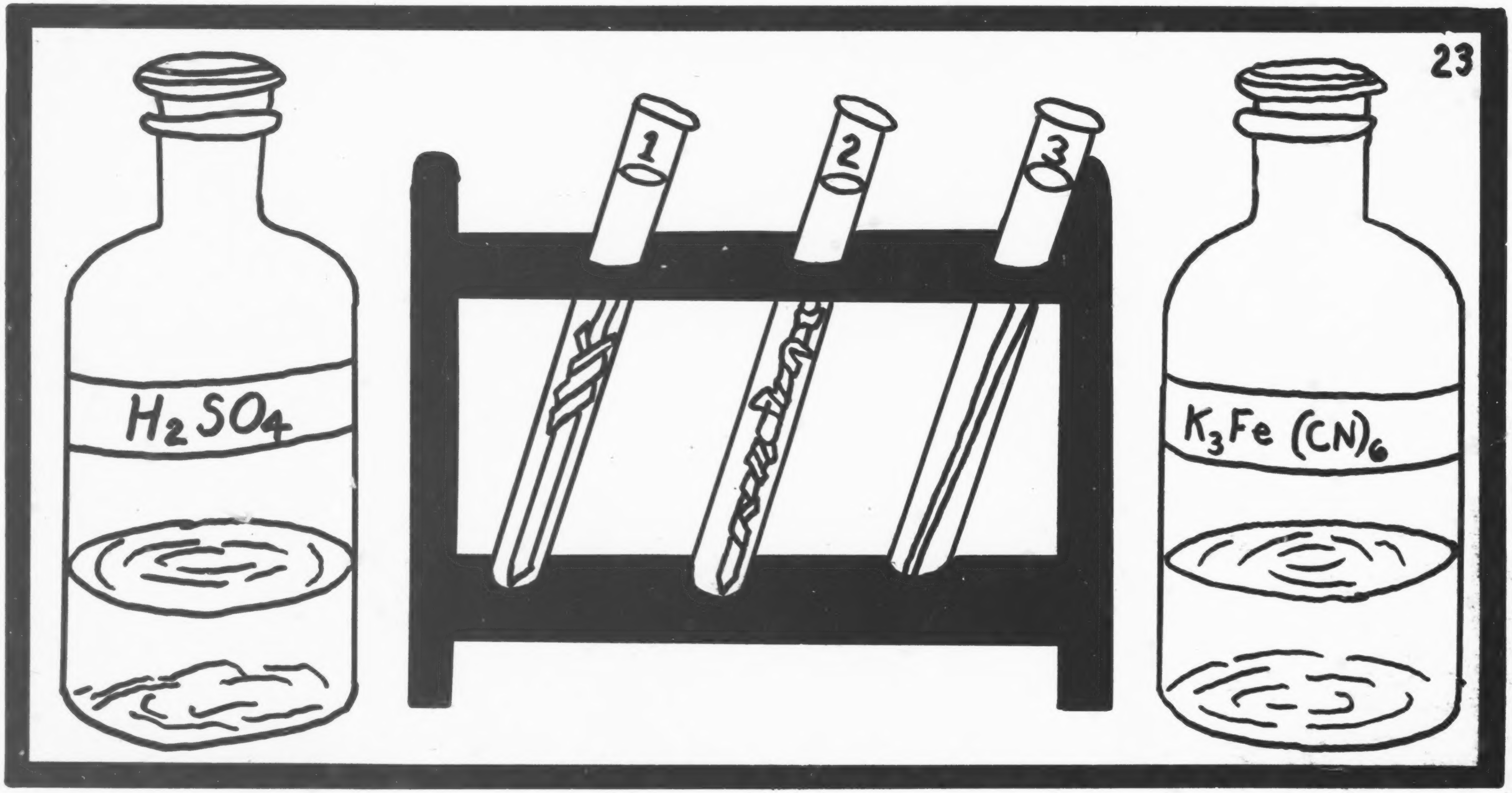
SPRAYING

1. ZINC
2. CADMIUM
3. LEAD
4. ALUMINUM
5. TIN
6. NICKEL
7. COPPER
8. BRONZE
9. HIGH CARBON STEEL

COMMON BIMETALS

a. steel-copper
b. steel-brass
c. steel-nickel


Carbon steel
HNO3
Stainless Steel


23
H_2SO_4
1
2
3
$K_3Fe(CN)_6$

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Lothar W. Koppe
San Francisco State College
San Francisco, California

INSTRUCTIONAL LEVEL: Junior High - Senior High

TITLE: The Elastic Range of the Stress-Strain Curve

PRESENTATION TIME: one period

INTRODUCTION:

This unit should serve to introduce the students to the elastic portion of the stress-strain curve. The main point to bring over to the students is that all metals have an elastic range, even all materials have an elastic range--there is no such thing as an extremely rigid material which does not flex.

OBJECTIVES:

I have found that very few junior high school metals instructors deal with elementary topics which are related to metallurgy. Even senior high school teachers are lagging behind in that they fail to give the students a transition or preparation between grade levels. My primary aim is to demonstrate that with some very rudimentary teaching aids the instructor can bring over points which students would otherwise have difficulty in understanding.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:

The stress-strain curve and elastic properties can easily be applied to wood, plastics, and to a certain degree to ceramics.

USE IN INDUSTRY:

The elastic properties of metals are an extremely important factor in the metals construction industry. Anything from bridges to airplanes depend on the shock absorbing properties of the elastic range of metals.

MATERIALS AND EQUIPMENT:

Overhead transparencies and several teaching aids are needed to present this unit.

EDUCATIONAL MEDIA:

Overhead Transparency of Stress-Strain Curve
Rubber Tube Elasticity Teaching Aid
Strain Gage Apparatus Showing Bending and Torsion

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

The strain gage apparatus must be shrouded to prevent shock.

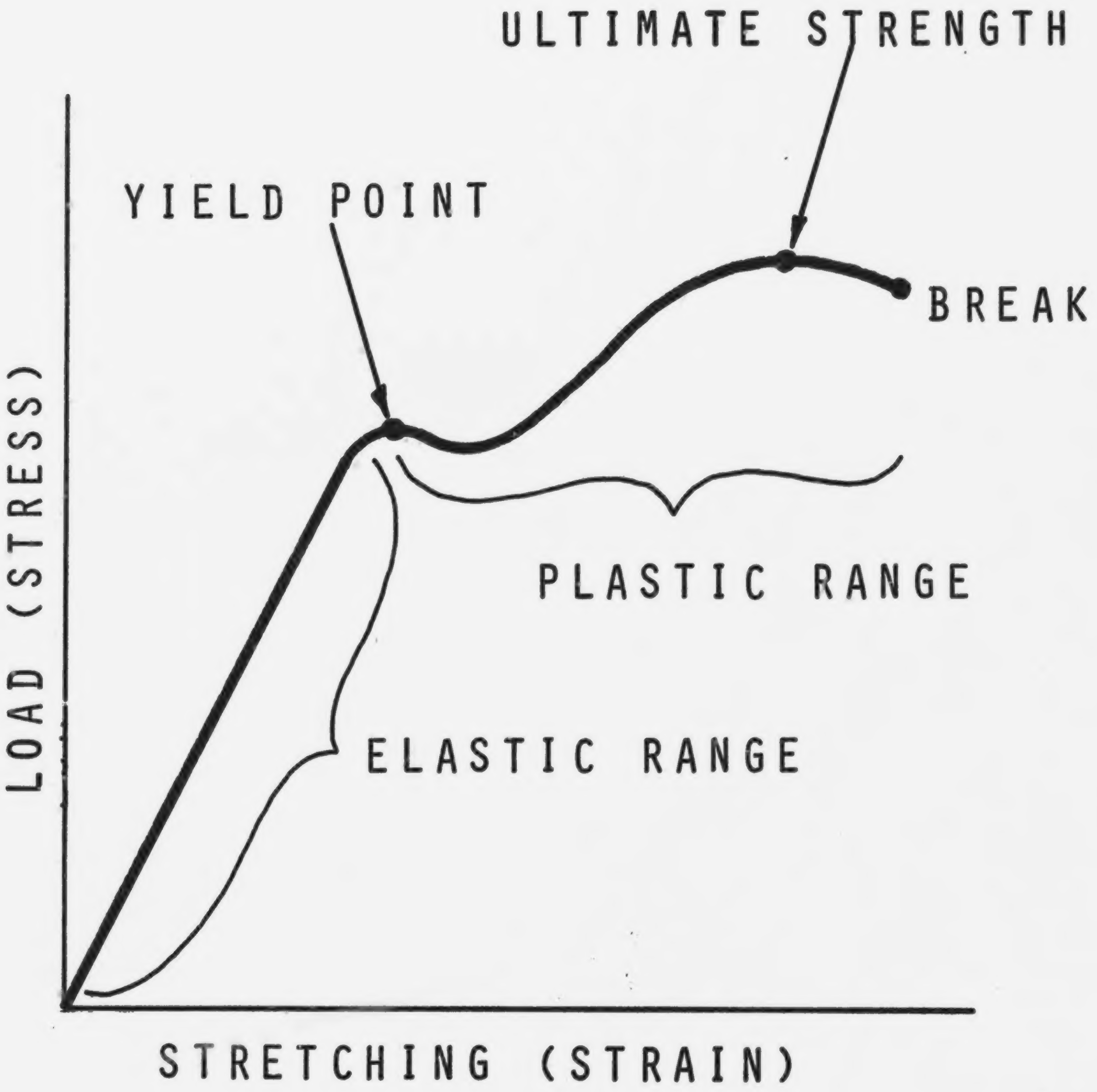
PRESENTATION:

(Oral presentation interrupted with teaching aids)

Metals,when subjected to tension, compression, or torsion, will demonstrate similar characteristics to a lesser or greater degree. If a metal is subjected to limited tension, it will demonstrate elastic properties, the material will act like a rubber band, that is, when the load is released the metal returns to its original length with no sign of distortion. If one were to subject the metal to a much higher load so that the elastic limit is reached, (see diagram 1) it will be seen that the metal will yield or be distorted permanently. This point at which distortion commences, is known as the yield point. When a still greater load is applied to the metal, work hardening may occur (e.g. brass) which means that the metal is becoming stronger as the distortion increases. This process continues to the ultimate strength point. Hereafter, the load is further increased, the metal distorts more and begins to show lower strength due to massive internal damage. This weakening continues up to the fracture point.

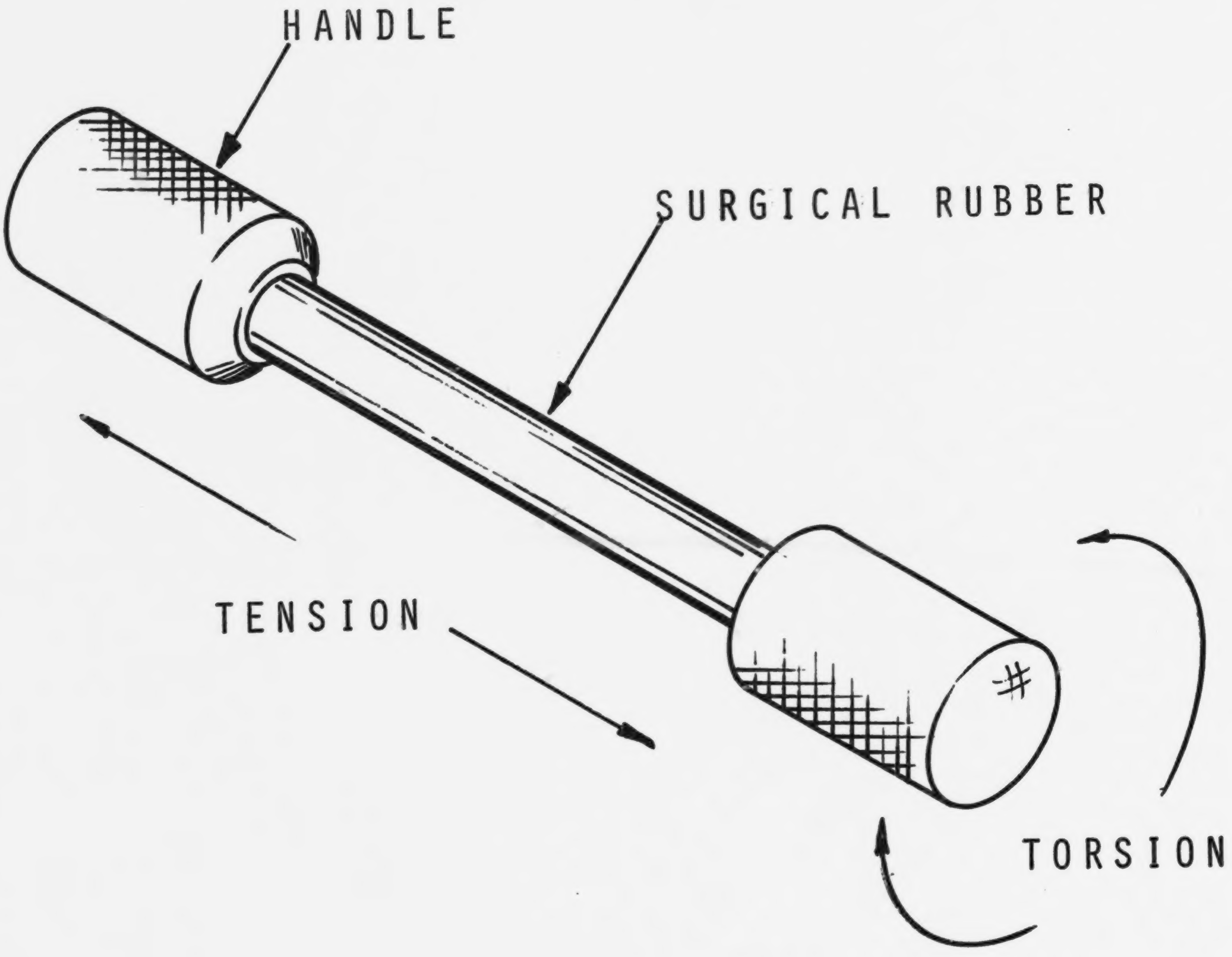
The elastic range can be easily demonstrated by stretching an 18" piece of 1/2" diameter surgical tubing (see figure 2). This demonstration also shows the reduction in cross-sectional area under tension which is associated with strain (stretching). Torsion can also be demonstrated by using the same tubing, orienting it in a vertical position and twisting the lower end and then releasing it. Again the point that metals demonstrate elasticity is clearly shown by the rubber analogy.

An application of the elasticity of metals for measurement is the strain gage. This device is usually a small photoetched metal pattern (1/4" x 1/4") which is bonded to a metal structure which will be flexed. The difference in cross sectional area of the metal pattern of the gage will vary the conductivity if a current is passed through the gage. If a suitable amplifier is built, a good torsional and bending reading can be obtained. A drawing of such a teaching device is shown in figure 3.



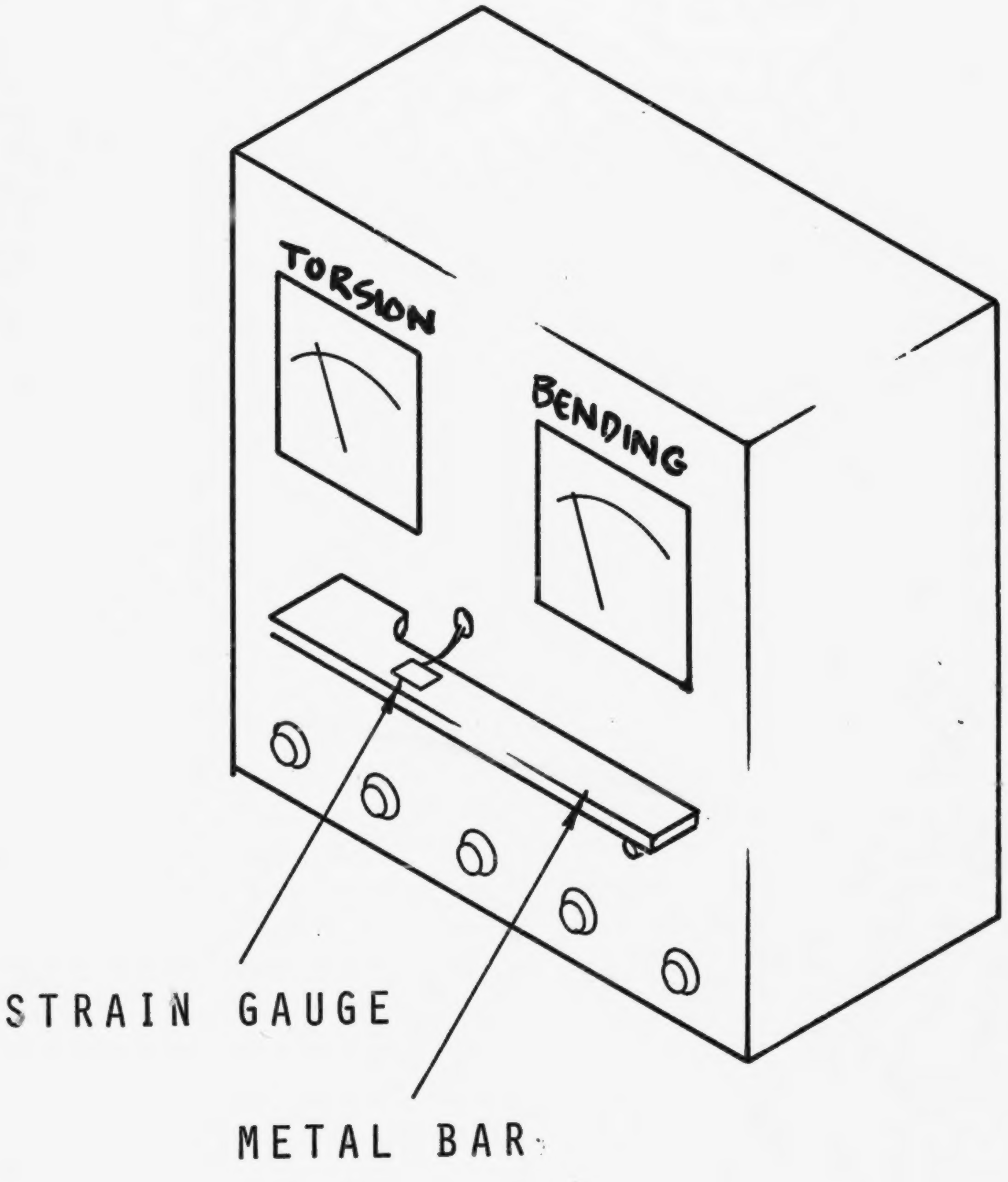
STRESS-STRAIN CURVE
FOR ELASTIC RANGE UNIT

DIAGRAM 1


HANDLE
SURGICAL RUBBER
TENSION
TORSION

RUBBER TORSION-TENSION DEMONSTRATION DEVICE

FIGURE 2


TORSION
BENDING
STRAIN GAUGE
METAL BAR

STRAIN GAUGE APPARATUS

FIGURE 3

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Don Whaley
Georgia Southern College
Statesboro, Georgia

INSTRUCTIONAL LEVEL: College (can be modified for high school or Junior high school

TITLE: Ferrous Metals

PRESENTATION TIME: 2 periods

INTRODUCTION:

Iron is one of the first metals used by man. It has only been during the last 200 years that man has begun to understand this useful material. It is by no means the most abundant material and yet most of the economy of the world today is tied closely to the processing and fabrication of iron. In order to understand the importance of this material to our modern technological society we must gain a greater understanding of iron. Why is it so useful to man, how does it react to man's experimentation, and how does it compare with other metals are just a few of the questions studied in this unit.

OBJECTIVES:

1. To develop understanding of the element iron and its relationship to other elements.
2. To develop insights into properties of iron.
3. To develop understanding of the internal structure of iron.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals or Material Science

INTER-RELATION WITH OTHER SUBJECTS:

Geology: This unit should complement the study of geology because of its relation to earth formations, meteorites, and make-up of the universe.

Chemistry: Knowledge of the structure of matter is presented for review so that students will understand the internal make-up of metals. The elements will also be discussed for comparative purposes.

Physics: Principles of physics will be brought to the attention of students for practical application in the study of metals.

Mathematics: Formulas, charts, and graphs should be used to supplement the material covered.

USE IN INDUSTRY: Man is constantly searching for new ways to use this relatively abundant metal. Therefore the field of metallurgy as associated with iron and steel industries will have continued need for metallurgists, engineers, and technicians for carrying on this research work. All of us are consumers of this metal.

MATERIALS AND EQUIPMENT:

1. Small magnet.
2. Metal samples - sodium, copper, steel, non-aluminum, lead
3. Charts - Periodic, Electro-motive series, Chart of metals
4. Overhead projector
5. Samples of iron ores - Hematite, Magnetite
6. Samples of meteorites

EDUCATIONAL MEDIA:

1. Overhead transparencies
2. Charts, Periodic chart of elements, metals, electromotive series chart.
3. Lecture - Demonstrations

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Safety must be stressed especially where very reactive metals are concerned. If students or instructors handle these metals, rubber gloves should be worn. Goggles are always necessary when working with any kind of chemicals. Tongs should be used for picking up reactive metals.

PRESENTATION:

A. Identification and Definition
   1. Atomic number 26
   2. Valence 2 and 3
   3. Atomic weight 55.85
   4. Symbol fe from Latin word Ferrum
   5. Description: This most important metal is one of the triads grouped with cobalt, and nickel on the Periodic Chart of Elements. Its color is grayish white(pure) and it is relatively soft. It possesses one very important characteristic which places it among the most important metals man has at his disposal. This is its ability to change from one cubic lattice arrangement to another when heat energy is applied. This change, known as allotropic, makes possible physical property

changes of the metal iron for more useful purposes.

Chart: Refer to the periodic chart of elements for location of iron.

B. Meteoric iron and the iron content of the earth

Transparency #1, Chemical Elements

1. First uses of iron were probably meteorites which man picked up much the way he picked up stones and obsidian from which he made weapons and tools.
    - a. Meteorites contain mostly iron with small amounts of nickel and cobalt.
    - b. Pre-historic man had no way to analyze material other than through performance of the material. Although it took him longer to form tools or weapons from the "stones from heaven," he surely could recognize the improvement over stone materials.

Student assignment: Make an independent study through reference material in the library concerning meteorites. Prepare a research paper concerning meteorites and make-up of the universe. Note! This assignment is made for college level students and should be modified for junior and senior high students.

Alternate assignment: Prepare a research paper concerning the first uses of iron by pre-historic man.

Instructional Activities: 1. Bring in samples of meteorites.
2. Bring in pictures and information concerning meteorites

C. Review of Periodic Chart

1. The purpose of the Periodic Chart
    - a. Knowledge of the atom.
    - b. Information for study and research.
2. The chart contains some thirty facts concerning each element on the molecular level.
    - a. Atomic number is the distinctive characteristic of the atoms.
    - b. Atomic weight
    - c. X-ray permits the assignment of natural serial number.
    - d. Each atom is placed on the chart according to the number of protons in the nucleus, the number of shells and the number of electrons in each shell.
3. Some of the wealth of data that can be found on the periodic chart are:
    - a. Atomic number. Tinted black.
    - b. Atomic weight. Total weight of protons and neutrons in the atom. Grams per gram - atom one gram atom contains 6.02×10^{23} (Avagadros number)
    - c. Atomic diameter and volume - diameter of the sphere which just circumscribes the farthest excursion of the outer electrons in normal state.

d. Ionization Potential - The voltage necessary to give electrons sufficient momentum to detach an electron from an atom upon collision.

e. Valence electrons - the column number (Roman numeral) number of "planets" in the outer shell

f. Crystal lattice or atomic geometry.

4. The chart shows at a glance the state of every atom

a. Whether it be solid, liquid, or gas at ordinary temperatures.

b. It also shows neutral and inert atoms.

Student assignment: Make a careful study of the periodic chart and be able to obtain information needed for understanding metals.

D. Physical, Chemical, and Mechanical Properties of Pure Iron

1. Definition of Properties.

a. Physical. The characteristics that are used to describe a material under conditions that exclude an external force. In other words, the properties that are within the material itself.

b. Mechanical. The characteristics of materials that describe their behavior under various and varying external conditions or forces.

Transparency #2, Iron Transformation

c. Chemical. The solubilities, corrosion properties and characteristics.

2. Relative Reactance of Iron (susceptibility to corrosion)

a. Iron is found in nature as a mixture - composed of materials such as clays, soils, sands, etc. It is found in nature as:

1) Silicates

2) Chromite

3) Sulphide FeS_2

4) Carbonate $FeCO_3$

5) Oxides Fe_2O_3 and Fe_3O_4 (Fe_3O_4 is magnetic)

b. Refine ore - through oxygen reduction.

1) Mechanical separation of ore from waste materials

2) Chemical reaction for final separation. Use oxygen as reducing agent.

c. Corrosion - iron has a natural affinity for oxygen.

1) Corrosion takes place when iron is exposed to air

2) This procedure can be stopped only by providing some kind of barrier (coating) between the iron and oxygen present in the atmosphere.

Demonstration: Very reactive - reactive - moderately reactive metals

   d. Some metals are more reactive than iron, but they have the ability to protect themselves by building up an oxide coating which inhibits penetration of oxygen to farther depths. Example: copper forms copper oxide on its surface which shields the metal underneath. Aluminum also has this characteristic.

Demonstration scratching a piece of lead and allowing students to observe the coating formation.

   e. Pure iron, which has most of its impurities removed is more corrosive resistant than iron which contains percentages of carbon, silicon, sulphur, manganese, and other elements.
   f. Wrought iron, which is an extremely expensive material, is iron which is purified substantially, but not completely, alloyed with silicon for toughness, has good corrosive resistance.
   g. There is no pure iron except in laboratory situations. The cost is quite prohibitive.

3. Density and Specific Gravity of Iron
   a. Density = 487 lbs/cubic ft.
   b. Specific gravity = 7.8
   c. When compared with other metals, the density of iron falls near the center.

Transparency #3, Metal Density, Comparison

4. Magnetic Properties
   a. Iron is very magnetic in its pure and impure state
   b. The ores which contain Fe_3O_4 are magnetic
   c. Scientists estimate that the core of the Earth is molten iron, which accounts in part for the magnetic field which exists around the Earth.

Demonstration: Magnet and different kinds of metals - to illustrate the magnetic property of ferrous metals. May also use small particles of different kinds of metals and see which ones the magnet will pick up.

5. Thermal and Electrical Conductivity
   a. Electrical and thermal conductivity is very dependent on the nature of the atomic bond.
      1) Ionic and covalent bonded materials are poor conductors.
      2) Metallic bonded materials are usually good conductors because of the free electrons which move through the material.
   b. Iron is not considered a good conductor of electricity.

Transparency #4, Electrical conductivity percentage series chart.

   c. Iron is useful in heaters, etc, because it holds heat very well

6. Melting Point

Transparency #5, Melting Point Comparison Table

   a. As with other materials, iron in the pure state (99.9%) has a higher melting point than in an impure state.
   b. Carbon, and other impurities, tend to lower the melting point.

7. Relationship to Electromotive series

   a. The electromotive or electro chemical series is an arrangment of some metals in the diminishing order of their tendency to oxidize or corrode.

Transparency #6, Electromotive chart

   b. Potassium reacts by burning when in contact with water.
   c. Gold and platinum are unattracted by most chemical reagents.
   d. Oxidation and corrosion of those metals at the top of the list takes place at ordinary temperatures.
   e. Hydrogen is the dividing point
   f. Copper and those below it do not oxidize at ordinary temperature when exposed to pure dry air.
   g. Metals above hydrogen are not found free in nature.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

1. Outside assignments related to this unit, concerning iron, and its relationship to other elements.
2. Unit test: should be prepared and administered by the individual instructor.
3. Lab exercises designed to show reactiveness of metals
4. Prepare static displays and build models of atomic structure of iron and other elements.

UNIT EVALUATION:

Evaluation of the unit should be conducted by the instructor to determine whether or not he has met his objectives.

1. Unit test should be carefully constructed and the results considered.
2. Student interest - by response to questions during the course of presentation of the unit also become important
3. Student questions during presentation.
4. Quality of assignments.

DEFINITION OF TERMS:

1. Atomic number - total number of protons in the nucleus of an atom.

2. Valence - electrons in the outer shell of an atom, which can be dislodged or moved out of atom.
3. Atomic weight - total weight of protons and neutrons in the atom.
4. Allotropic - ability of a metal to change from one cubic structure to another when heat is applied.
5. Ionization potential - the voltage necessary to give electrons sufficient momentum to detach an electron from an atom upon collision
6. Inert atoms - atoms which have completely filled outer shells; will not combine easily with other elements.
7. Density, specific gravity - The weight of a substance compared to the weight of an equal volume of water.

REFERENCES:

STUDENT:

1. Elements of Material Science, Addison-Wesley Pub. Co. Reading, Mass.
2. Introduction to Physical Metallurgy, McGraw-Hill Pub. Co., New York, N.Y.
3. Metallurgy, American Tech. Society, Chicago, Ill.

TEACHER:

1. Principles of Modern Metallurgy, Charles E. Merrill Pub. Co., Columbus, Ohio.
2. The Making, Shaping, and Treating of Steel, U.S. Steel Corp., Pittsburg, Penn.
3. Metallic Material, Holt, Rinehart & Winston, Inc. N.Y.
4. The Nature of Metals, American Society for Metals, Cleveland, Ohio.
5. Metallic Materials in Engineering, Macmillan Co. N.Y.
6. Elements of Material Science, Addison-Wesley Pub. Co., Reading, Mass.
7. A.S.T.M. Handbook Standards, Vol 1,2,3, American Society for Testing and Materials, Philadelphia, Penn.

STUDENT LAB ASSIGNMENTS:

Explanation: This series of lab assignments can be used by the instructor at his own discretion. Some may not be appropriate for his purposes and the needs of the students. The assignments are designed so that the student is given the opportunity to think through the problem and bring his own ideas into the solution.

Assignment #1 Thermal Conductivity of Ferrous Metals

Problem: To determine the thermal conductivity of the different kinds of ferrous metals and to compare them with other metals.

Equipment needed:

1. Timer or stop watch
2. Heat source - bunsen burner or others.
3. Support hardware such as a ring stand

Materials needed:

1. Strips of ferrous metals - varying carbon content. 1" wide, 8" long
2. Strips of sluminum and copper 1" wide, 8" long
3. 1/8" cubes of paraffin

Safety:

1. Use asbestos gloves when working with hot metals.
2. Use tongs to hold metals when hot.

Procedure: Mount the strips in such a way that heat can be applied evenly on all parts. Place the paraffin cubes on each strip at the same distance from the end. Heat the strips on the opposite end and record the time it takes for each paraffin cube to melt.

Questions to be Answered by Experiment:

1. What is the comparison of thermal conductivity in ferrous metals with different carbon content?
2. What is the comparison of thermal conductivity of ferrous and non-ferrous metals?
3. How does thermal conductivity of the metals compare with the electromotive series of these metals?
4. What is the cooling rate of each metal?
5. How does thermal conductivity compare with melting temperature of these metals?
6. Is there any change in data when the experiment is run the second time?

Assignment #2 Reactiveness of Metals

Problem: To determine the reactive nature of metals with understanding of terms, very reactive, reactive, and moderately reactive as they are applied to metals reaction with other materials.

Equipment needed:

1. Heat source, bunsen burner, or others.
2. Beakers 400 ml.
3. Ring stands to hold beakers.
4. Thermometer.

Materials needed:

1. 50/50 sulphuric acid

2. 50/50 nitric acid
   Note: these solutions may need to be more concentrated if the 50/50 solutions show no reaction.
3. Tap water
4. Small particles of sodium, potassium
5. Small particles of steel, zinc, copper, aluminum and others.

Safety:

1. Very reactive metals such as Na and K are dangerous. Never touch these materials or have them come in contact with the skin.
2. Always wear goggles and rubber gloves when working with reactive materials and acids.
3. Use tongs to handle Na and K.
4. Always pour acid into water when diluting.
5. Rubber or plastic aprons should be worn when working with chemicals.

Procedure:

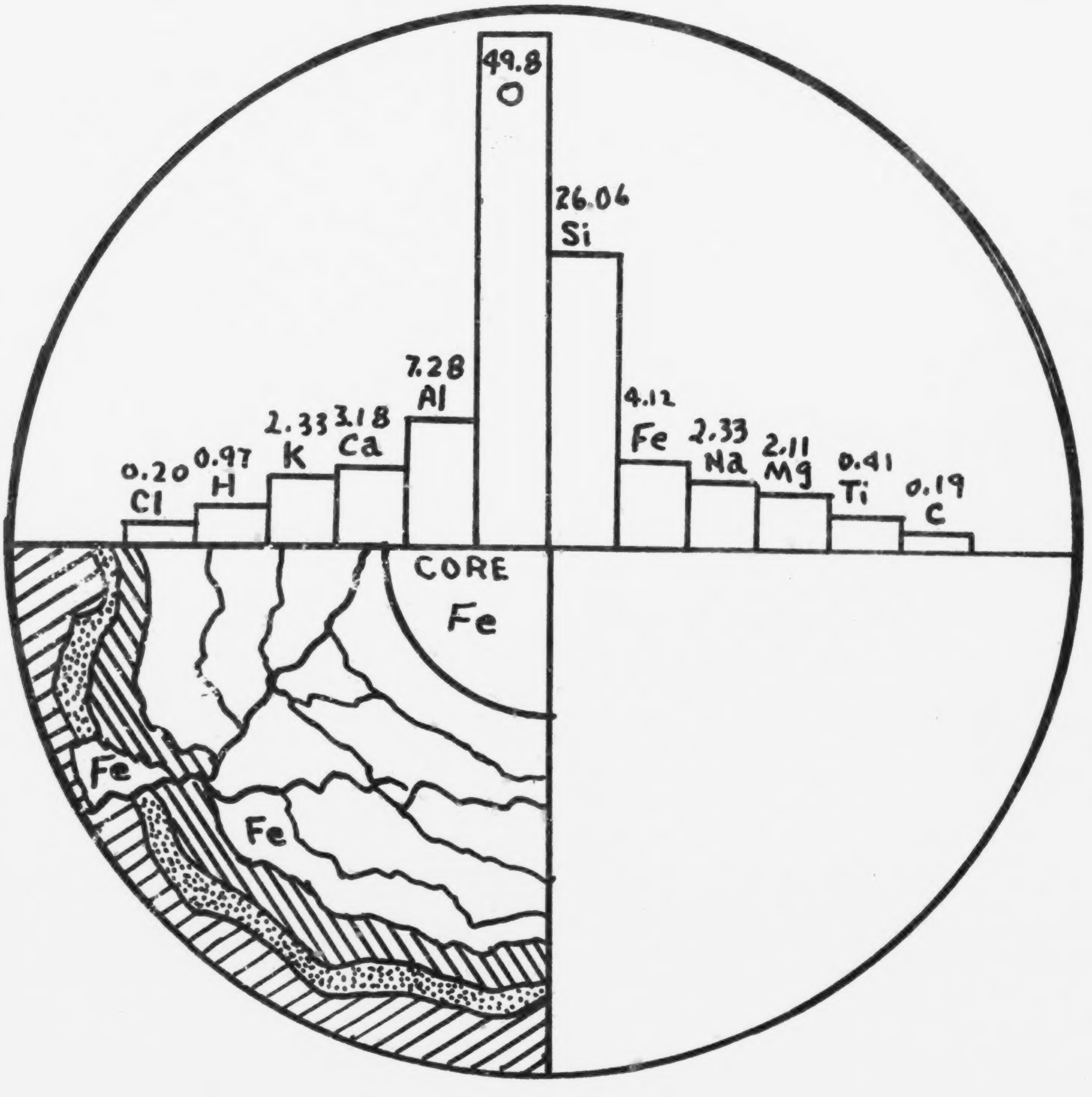
1. Into two beakers place ordinary tap water. In one of the beakers put small particles of steel, aluminum and copper. Note the reaction.

2. Into the other beaker place a small amount of Na. Note the reaction.
3. Using a third beaker put in a small amount of 50/50 sulphuric acid. Place a particle of copper or aluminum in the solution. Note the reaction.
4. Using a fourth beaker, put in a small amount of 50/50 nitric acid. Place a particle of steel into the solution. Note the reaction.
5. Repeat some of the above experiments but use heat to see if any change in reaction occurs.
6. Keep a log of all your observations.
7. Use your own imagination and experiment with solutions and metals to obtain reactions.

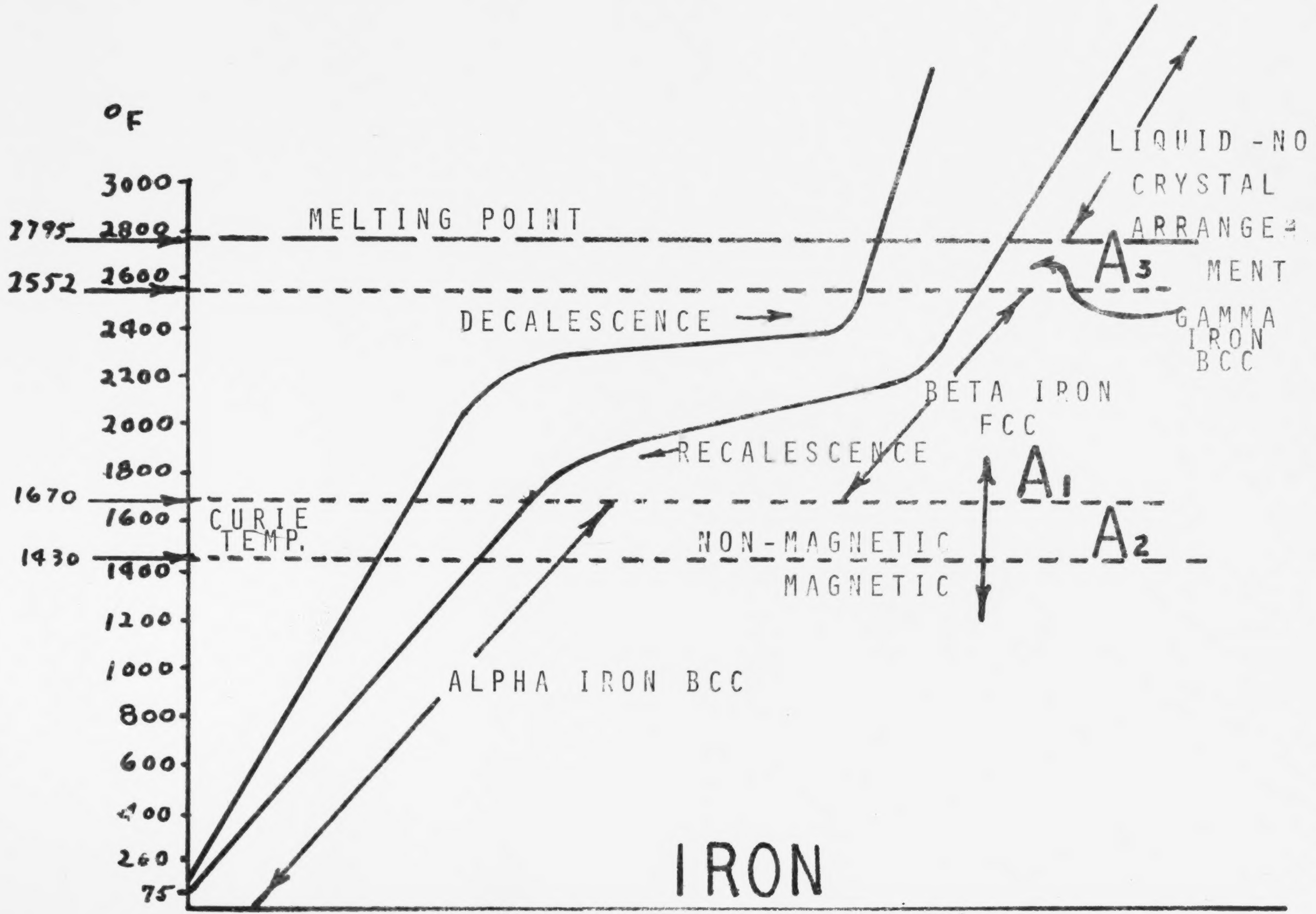
Questions to be Answered:

1. What do we mean by very reactive, reactive and moderately reactive metals?
2. Why is Na and K so very reactive?
3. Why is aluminum, which is considered very reactive so difficult to destroy?
4. What part does heat play in the breakdown of metal?
5. What solutions may we use to keep Na and K from destroying itself?

CHEMICAL ELEMENTS



% IN EARTHS CRUST



IRON TRANSFORMATION

METAL	DENSITY
Pt	21.45
Cu	8.96
Fe	7.87
Al	2.70
Li	.53
WATER	1.00

ELECTRICAL CONDUCTIVITY

METAL	PERCENTAGE
SILVER	100.00%
COPPER	95.00%
GOLD	66.00%
ALUMINUM	53.00%
MAGNESIUM	35.50%
MOLYBDENUM	32.20%
TUNGSTEN	28.09%
ZINC	26.0 %
CADMIUM	21.2 %
IRON	17.7 %
PLATINUM	16.4 %
COBALT	16.3 %
NICKEL	11.8 %
TIN	11.3 %
LEAD	7.6 %
ARSENIC	4.6 %
BISMUTH	1.1 %
MANGANESE	--- %
BERYLLIUM	--- %
SILICON	--- %
PALLADIUM	--- %
CHROMIUM	--- %

METAL	MELTING POINT
PT	1769° C
FE	1539° C
CU	1083° C
AL	660° C
LI	186° C

ELECTRODE POTENTIAL OF METALS

METAL ION	POTENTIAL
Li^+ (BASE)	+2.96 (ANODIC)
K^+	+2.92
Ca^{2+}	+2.90
Na^+	+2.71
Mg^{2+}	+2.40
Al^{3+}	+1.70
Zn^{2+}	+0.76
Cr^{2+}	+0.56
Fe^{2+}	+0.44
Ni^{2+}	+0.23
Sn^{2+}	+0.14
Pb^{2+}	+0.12
Fe^{3+}	+0.045
H^+	0.000 (REF)
Cu^{2+}	-0.34
Cu^+	-0.47
Ag^+	-0.80
Pt^{4+}	-0.86
Au^+ (NOBLE)	-1.50 (CATHODIC)

AN ACTIVE METAL WILL DESTROY ITSELF BY GIVING UP ELECTRONS TO A LESS ACTIVE METAL. THE ACTIVE OR DONOR METAL IS CALLED THE ANODE - THE ACCEPTOR IS CALLED THE CATHODE.

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: William Velez Cuevas
San Juan Education Region
San Juan, Puerto Rico

INSTRUCTIONAL LEVEL: Junior High School

TITLE: Honeycomb Metal

INTRODUCTION:

Honeycomb metal is playing an increasingly important role in our metal industry. It is used in NASA's Apollo program not only as a means to provide needed strength at lowest weight, but also to solve some unusual energy absorption, insulation and ablation problems.

Weight reduction and strength are the primary reasons for choice of honeycomb over conventional materials and method of construction.

OBJECTIVES:

1. To develop a familiarity with materials uses and the process for making honeycomb metal.
2. To develop a familiarity with properties of honeycomb metal.
3. To develop an interest in further experimentation and research.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metal

INTER-RELATION WITH OTHER SUBJECTS:

1. Mathematics: The students should be familiar with the different geometrical forms of the honeycomb core. Also he is going to relate himself with the scale that is used for weighing the different metal samples.
2. Science: Students should be familiar with the chemical process that takes place while bonding the different elements of the sandwich structure.
3. Other materials used in the Honeycomb Sandwich: The student should be familiar with other materials that are used in the honeycomb products, its properties, how they are used and why. These are:
   a. Paper
   b. Fiberglass

   - c. Cement asbestos
   - d. Thermoplastics or elastomeric resins
   - e. Glass fabric plastic
   - f. Cotton
   - g. Titanium

USE IN INDUSTRY:

Since World War II, designers of air and space craft have made ever-increasing use of honeycomb in a great variety of structural and non-structural applications. Today it is used in

1. The Apollo spacecraft command module for:
   - a. Crew compartment structural shell
   - b. Astronaut shock protection
   - c. Heat shields
   - d. Crew compartment shock protection
   - e. Ablative heat shields
   - f. Structural support
2. In aircraft, aerospace and automobile for duplicate die model and control tooling.
3. For replacing heavy multi=layer laminates or plasters.
4. To make up curved control tool surfaces.
5. As an energy absorption.

Another industrial application recommended is for use in doors, furniture, small buildings and recreational equipment.

MATERIALS AND EQUIPMENT:

1. Transparencies
2. Overhead projector
3. Samples of fiberglass, stainless steel, aluminum and honeycomb
4. A scale, electric oven, compress machine

EDUCATIONAL MEDIA:

1. Transparencies of:
   - a. Variety of honeycomb cell
   - b. Honeycomb sandwich structure
   - c. Table of weights and deflections of honeycomb sandwiches.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

1. Use face shields or safety glasses while applying pressure to metal samples.
2. Use gloves while handling hot metals.
3. To avoid burning, place hot samples in a clearly marked container until cool.

PRESENTATION:

1. Lecture-demonstration
    - a. Using an overhead projector, show the transparency of the three elements that make up a honeycomb sandwich panel. Explain how it is made.
    - b. Show the other transparencies and explain its material.
2. Experiments:
    - a. The students should weigh the samples of metals.
    - b. The samples should be tested for crush strength, rigidity and heat resistance fatigue.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Questions to be answered during experiments:

- a. Which of the samples weighs less?
- b. Does heat affect honeycomb metal? How?
- c. Which of the metals resist more pressure?
- d. Which are the characteristics of the honeycomb metals?
- e. Which material was used as adhesive?
- f. What are the properties of the adhesive material?

UNIT EVALUATION:

Methods for evaluating success of unit:

- a. Observe student interest throughout the experiment.
- b. Determine if they understood the scientific principles involved.
- c. They could determine the characteristics of the honeycomb metals by the experiments.

DEFINITION OF TERMS:

1. Honeycomb - a design of material which has the form of a honey bee panel structure.
2. Core - center of the bar, inside of the case (heat-treating)
3. Bonding Material - the material used for maintaining the union of other materials by an adhesive.
4. Adhesive - a substance capable of holding materials together by surface attachment
5. Thermal - pertaining to, determined by, or measured by heat

6. Fatigue Resistance - resistance to the tendency to fracture under cyclic stresses.
7. Rigidity - the property of resisting elastic deformation.
8. Environmental - the product should be manufactured in such a way that environment changes do not affect it adversely.

REFERENCES:

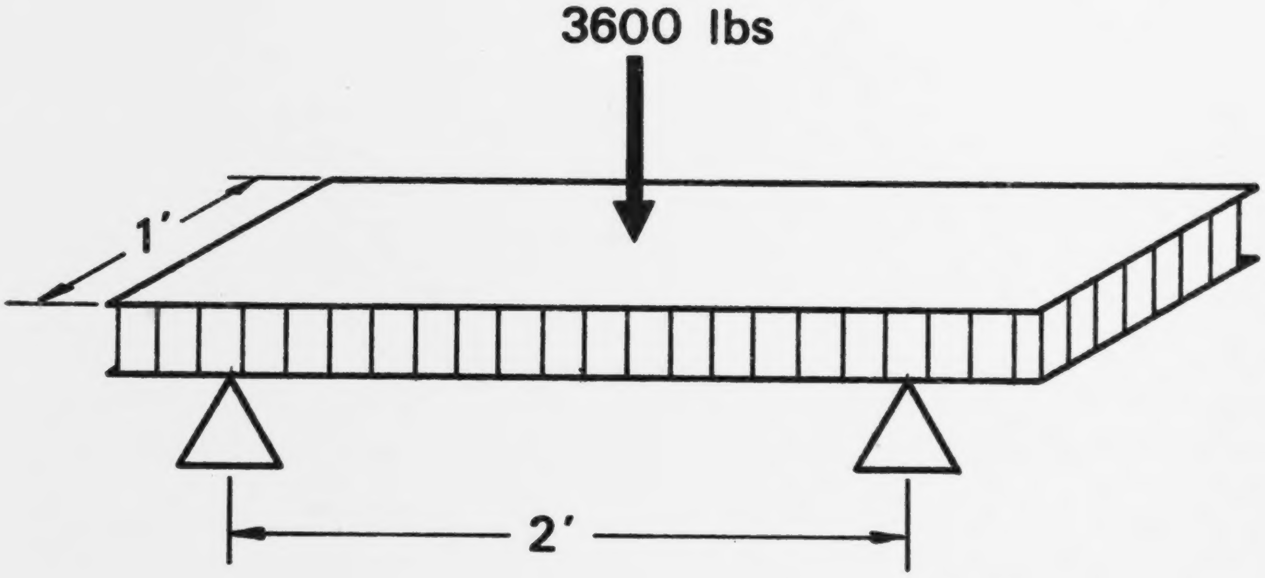
STUDENT:

1. An information sheet prepared by teacher

TEACHER:

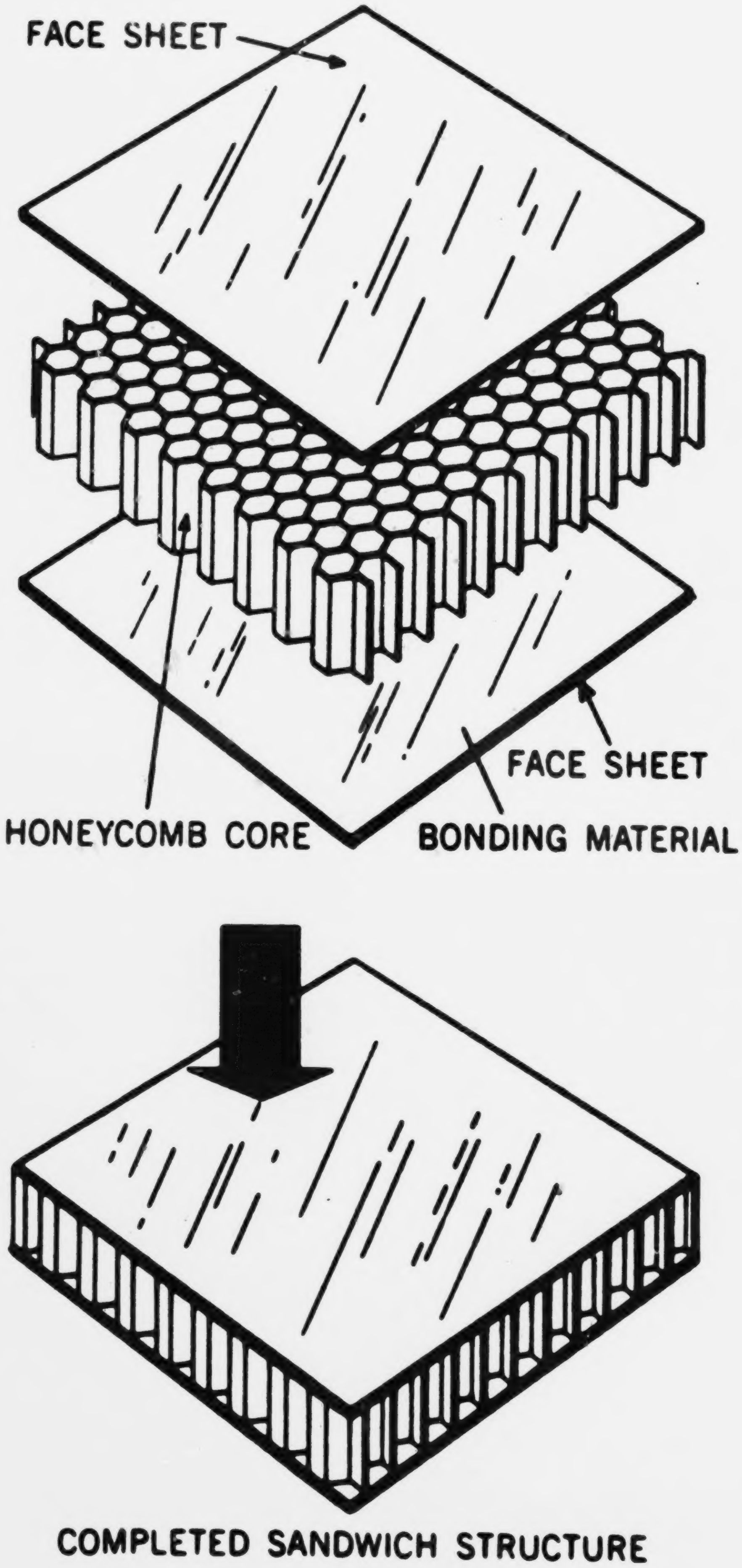
1. Committee of Industrial Arts Educators, A Space Technology Conference for Industrial Arts Educators, Florida, 1966, pp. 133-139.
2. Committee of Industrial Arts Educators, Space Resource for the High School, Washington, D.C., 1967, pp. 142-146.
3. Hexcel Products, Inc., Dept. D-Z, Designing With Hexcel Honeycomb, California, 1964.

WEIGHTS AND DEFLECTIONS OF HONEYCOMB SANDWICH PANELS



3600 LB. WEIGHT------- 24"SPAN

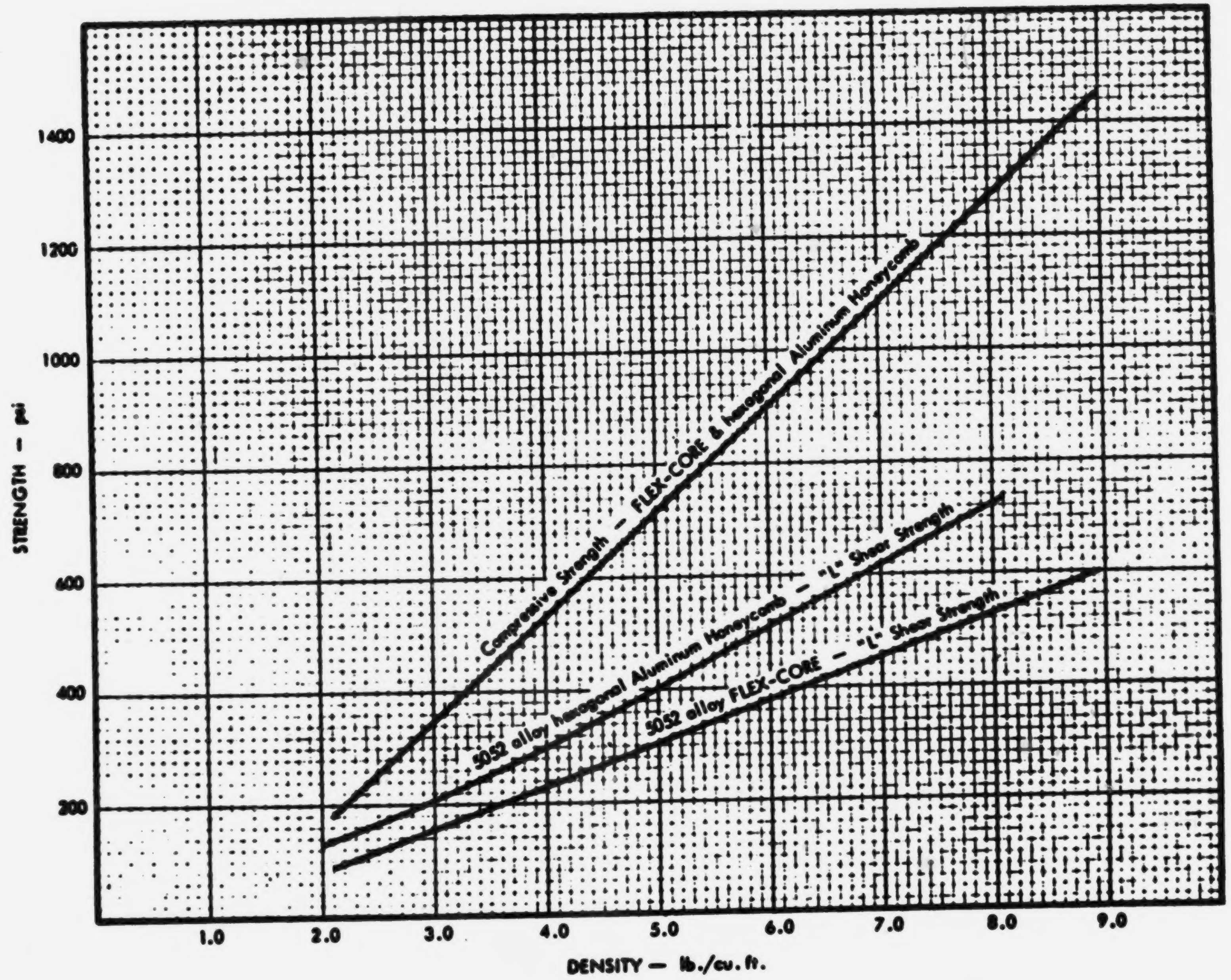
MATERIAL	DEFLECTION (IN INCHES)	WEIGHT (IN POUNDS)
HONEYCOMB SANDWICH	.058	7.79
NESTED "I" BEAMS	.058	10.86
STEEL ANGLES	.058	25.9
ALUMINUM PLATE	.058	34.2
MAGNESIUM PLATE	.058	26.0
STEEL PLATE	.058	68.6
GLASS REINFORCED PLASTIC LAMINATE	.058	83.4

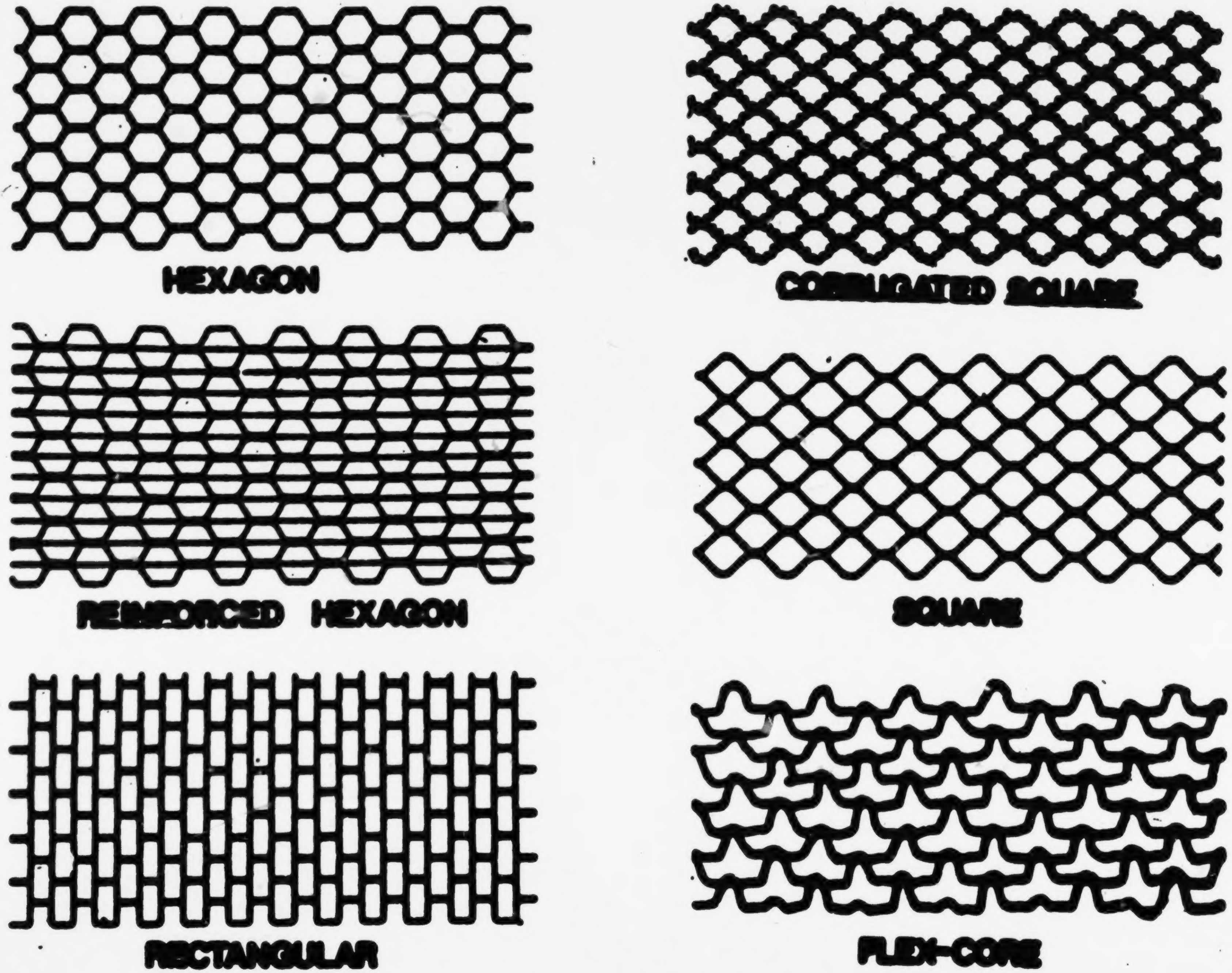

FACE SHEET
FACE SHEET
HONEYCOMB CORE
BONDING MATERIAL
COMPLETED SANDWICH STRUCTURE

Three elements make up a honeycomb sandwich panel: face sheets, core, adhesive.

PROPERTIES COMPARISON

Although Flex-Core is considerably more formable than conventional honeycomb it retains mechanical properties in the range of the hexagonal types of core materials. In the chart below comparisons of Compressive Strength and "L" direction Shear Strength are shown both for Flex-Core and conventional 5052 alloy hexagonal honeycomb.




HEXAGON
CORRUGATED SQUARE
REINFORCED HEXAGON
SQUARE
RECTANGULAR
FLEX-CORE

Hexcel Corp.

2. Common types of honeycomb cell

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Arthur E. Muller
Stout State University
Menomonie, Wisconsin

INSTRUCTIONAL LEVEL: College

TITLE: Introduction to Cermets

PRESENTATION TIME:

INTRODUCTION:

The material now defined as a cermet has been with us about 40 years, with the greatest development of usable variations reached during the last 20 years. An important industrial tool that has been on the scene since the 1920's is the common cemented tungsten carbide cutting tool used in so many applications.

The greatest research effort has been to develop to a satisfactory degree the resultant desirable properties and characteristics of these two common materials, ceramics and metals. Tensile strength and impact strength at elevated temperatures combined with toughness and resistance to oxidation and erosion has been an elusive combination of properties. When cermets are developed well enough to meet present technological needs, progress will be made at an even more rapid rate.

OBJECTIVES:

Student will become FAMILIAR with:
- the composite material cermets
- outstanding properties and characteristics of cermets
- material origin
- production methods
- application of cermets

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER RELATION WITH OTHER SUBJECTS:
ceramics, physics, chemistry

USE IN INDUSTRY:

Thermo-couple sleeves, rocket engine nozzels, refractory pouring spouts, industrial cutting tools, high temperature seals, disc brake inserts, crucibles for reactant metals, throw-away tool inserts, pump parts, valves, permanent molds, coatings, filaments (heating elements), abrasives, wire drawing dies.

MATERIALS AND EQUIPMENT:
metal cutting lathe or milling machine
tooling that uses replaceable inserts for either milling machine or lathe

EDUCATIONAL MEDIA:
Films- contact companies listed under references
Transparencies
Brochures & charts - contact companies

UTILIZATION IN THE TEACHING LEARNING ENVIRONMENT:

PRESENTATION:

1. Introduction
2. Definition of a Cermet
   A review of recent technical journals and references will produce some variations in the definition of "cermets". An all inclusive version might read thus: "A mixture of refractory metal powders and ceramic oxides which are pressed or cast to shape and then sintered." (Brady) Another definition: "... a material containing one ceramic phase and one metallic phase." (Campbell and Sherwood) The shortest yet found: "Practically any ceramic containing metal oxides."
3. Definition of an Oxide
   Compounds of oxygen with one or more of the metal or metalloid elements which are stable enough to be useful at elevated temperatures.
4. Definition of a Carbide
   A compound of an element, usually a metal, with carbon.
5. Powder Production Methods
   The production of metal powders warrants some consideration before discussing properties, characteristics and applications. How are particles as small as one micron produced? A micron is 10^{-6} meter or one millionth of a meter. The common production techniques for low melting point metals include Atomization which is accomplished by spraying a stream of molten metal through a nozzle into air or water. Particle size is regulated by nozzle size, flow rate, temperature and pressure. Powder production by the Reduction method involves heating iron oxide in a controlled atmosphere furnace to produce a sponge iron or pure porous iron. Temperatures are held below the melting point of iron. The sponge iron is finally crushed and ground to a desired particle size.

Electrolytic produced powders are made by plating at a high amperage which produces a "powder" on the cathode. The deposit is removed and pulverized to a desired finished particle size.

6. Types of Cermets

Two types of cermets have survived research and development to become useful materials: Oxide and Carbide based cermets. The cermet oxide family most frequently uses a chromium - aluminum oxide combination. The percentage of alumina (Al_2O_3), ranges between 70-80% and chromium 20-30%. Carbide based cermets are derived from two primary metals, tungsten and titanium. The earliest was tungsten carbide and a cobalt metal binder. Cobalt metal cemented the carbide particles to form a much stronger material than cast tungsten carbide. This material is common to industry in cutting tools but some authorities hesitate to classify it as a cermet. Titanium, tantalum, niobium (columbium), and other have been researched but have not yet equaled the old standby, tungsten carbide.

7. Physical Properties

The physical properties of cermets are composites of their respective parent materials. Noted properties include the heat resistance of ceramics, high strength at elevated temperatures (to 2400°F), good thermal shock resistance and moderate impact strength. The development of physical properties depends on a number of factors in the compounding, compacting, and sintering process. Properties related to strength depend upon how well the metal wets the ceramics during sintering, how much alteration is necessary to achieve setting, and the mutual solubility of composite materials. How much wetting is achieved depends also upon the compounding. Sufficient metal powder must be present to totally surround each ceramic oxide particle when the proper sintering temperature (to 3000° F. for 30 hours) is reached. Excessive amounts of metal powders will not decrease wetting but instead will weaken the structure in terms of compressive strength.

8. Chemical Properties

Chemical properties relate to type of bond achieved during sintering and to corrosion and oxidation resistance. Proper compounding formulations inhibit the development of oxide films to as little as 0.002 thick at 1800° F. for 300-500 hours of service in destructive atmospheres.

9. Electrical Properties

Electrical properties are given little attention in current literature as the compilation of information has just begun with this material.

10. Applications

Some cermets have been adopted widely and are serving industrial and domestic needs well. Some applications for cermets are

Thermo-couple sleeves
Rocket engine nozzles
Refractory pouring spouts
Industrial cutting tools
High temperature seals
Disc brake inserts
Crucibles
Throw away tool inserts
Pump parts
Valves
Permanent molds
Coatings
Filaments - Heat elements
Abrasives
Wire drawing dies

11. Future

Increased sophistication in science and technology is requiring materials not now available to withstand newly encountered environments. Many inventions have remained brain bound because of the lack of available materials or tools to construct the device. While some developments function satisfactorily as laboratory devices, the cost frequently remains prohibitive until materials and processes bring costs into practical consideration. Our high temperature technology of today and the future will force increased research of high temperature materials and bring about developments not yet possible. When and if the major limitation, low shock and low impact resistance of cermets is overcome, the cost of operation of present devices will be lowered due to longer life and decreased maintenance. The whole family of high temperature materials, ceramics, metals, oxides, carbides, borides, nitrides, and etc. are contributing collectively as composite materials to new advancements.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Representative exercises may be developed to compare machining speeds and feeds using the various common cutting tool materials. Other activities may not prove practical because of inability to perform activities without highly sophisticated apparatus.

UNIT EVALUATION:

Written examination
Written and/or oral report by student
Compilation of data from cutting tool exercise

REFERENCES:

1. High Temperature Materials and Technology, I. E. Campbell and E. M. Sherwood (eds.) 1967, John Wiley and Sons, Inc. New York.
2. Handbook of Metal Powders, Arnold R. Poster (ed.), 1966. Reinhold Publishing Corp., New York.
3. Processes and Materials of Manufacturing, Roy A. Lindberg, 1964, Allyn & Bacon, Boston, Mass.
4. Materials Handbook, George S. Brady - 9th ed., 1965, McGraw-Hill Book Co., Inc., New York.
5. Engineering Materials Handbook, Mantell, (ed.) 1958, McGraw-Hill Book Co., New York.
6. The Encyclopedia of Engineering Materials and Processes, Clauser, Fabian, Peckner, & Riley (eds.), 1963. Reinhold Publishing Corp., New York.
7. Materials in Design Engineering (periodical) Reinhold Publishing Corp.

METAL POWDERS

Misc.

MAG TAPE
LUBRICANTS
N. D. T.

Medical

DENTAL FILLINGS
  GOLD-SILVER
DIETARY IRON
WATER PURIFIERS

DISENFECTANTS
INSULIN
  ZINC, AL, FE

Agriculture

SEED CLEANING
FUNGICIDES

Pyrotechnics

FLASH BULBS
INCENDIARIES
FLARES
FIREWORKS
ADDITIVE TO
  EXPLOSIVES
THERMITE
TRACER AMM

Sintered Products

P. M.   CERMETS

Joining & Surfacing

ALLOYING MATERIALS
BRAZING FILLER
  METALS
SOLDERING (PASTE)

Pigment

"GOLD" PAINT
  (BRASS)
"SILVER" PAINT
  (AL)
INK PIGMENTS
METALLIC "GLITTER"
  PAINTS
ALUMINUM PAINT

POWDERS (cont)

PAINTS & PIGMENTS

1. "GILT" PAINTS
2. METALLIC FLAKE PAINTS
3. COLORING PIGMENTS - INKS & PAINTS
4. CORROSION RESIST PAINTS - ALUMINUN - ZINC

SINTERED PRODUCTS

1. POWDERED METALLURGY
2. CERMETS

SEE UNIT DEVELOPMENT

MISC.

1. MATERIAL TESTING (MAGNETIC PARTICLE)
2. RADIATION SHIELDING
3. MAGNETIC AUDIO & VIDEO TAPE
4. LUBRICANTS
5. INCANDESCENT & FLUORESCENT LIGHTS
6. ELECTRONIC PRINTED CIRCUITRY

CARBIDE-BASE CERMETS

Type (base) ➜	Titanium Carbide (TiC)[a]	Tungsten-Titanium Carbide ($WTiC_2$)[b]	Tungsten Carbide (WC)	Chromium Carbide ($Cr_{23}C_6$, Cr_7C_3, Cr_3C_2)[c]
Density, lb/cu in.	0.20-0.26	0.38-0.47	0.47-0.55	0.25-0.28
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	–	16.5-32.9	25.7-50.1	–
Coef of Ther Exp (68-1200 F), per °F	$4.3\text{-}7.5 \times 10^{-6}$	$3.5\text{-}4.0 \times 10^{-6}$	$2.5\text{-}3.9 \times 10^{-6}$	$5.8\text{-}6.3 \times 10^{-6}$[f]
Electrical Conductivity, % IACS	1.34-6.0	4.3-5.8	5.0-10.1	2.58-2.78
Mod of Elast in Tension, psi				
70 F	$42\text{-}57 \times 10^6$	$65.5\text{-}80.6 \times 10^6$	$61.6\text{-}94.3 \times 10^6$	–
1600-1800 F	$33\text{-}48 \times 10^6$	–	–	–
Tensile Strength, 1000 psi[d]				
75 F	26-134 (0-61)	118-145	130[e]	36-37 (0)
1500 F	45-94 (0-2.7)	–	–	20-42 (0.2)
1800 F	35-72 (0-2.4)	–	–	–
Hardness (Rockwell)	A73-A91	A90-A93	A85-A93	A88.5-A89
Impact Strength (unnotched Charpy), ft-lb				
75 F	1.5-16	5.3-8.9	–	–
1800 F	2.5-16	–	–	–
Transverse Rupture Strength, 1000 psi	122-236	125-350	175-460	100-120
Stress-Rupture Strength (100 hr, 1800 F), 1000 psi	8-28	–	–	–
Compressive Strength, 1000 psi	265-450	585-705	518-800	422-480

[a] Property range covers grades ranging from 17.5% to 90% TiC with different binder metal contents. [b] Property range covers various grades of different carbide-metal proportions. [c] The type of chromium carbide and the type of binder metal affects properties. [d] Elongation (%) in parenthesis. [e] Typical of one grade. [f] 68-576 F.

ALUMINA CERMETS

Type ➡	Chromium-Alumina	Molybdenum-Chromium-Alumina[a]
PHYSICAL PROPERTIES		
Density, lb/cu in.	0 21	0.22
Porosity. %	<0.25	<0.25
Melting Point (approx) F	336	—
Ther Cond, Btu/hr/sq ft/°F/ft	29[a]	—
Coef of Ther Exp, per °F	4.7×10^{-6}[b]	5.2×10^{-6}[c]
Spec Ht (calc), Btu/lb/°F	0.16	0.14
Poisson's Ratio	0.22	0.25–0.27
MECHANICAL PROPERTIES		
Mod of Elast in Tension, 10^6 psi	41×10^6	$37–39 \times 10^6$
Ult Ten Str, 1000 psi		
Rm Temp	21	—
800 F	20.5	—
1200 F	20	—
1500 F	19.7	—
1800 F	16.8	—
2000 F	11.7	—
Hardness (Rockwell)	C37	C45–55
Mod of Rupture, 1000 psi		
Rm Temp	45	55[d]
1800 F	27	55
2100 F	18	29
2400 F	4.6	12
Compr Str, 1000 psi	110	240
Mod of Rigidity, psi	17×10^6	15×10^6
Shear Str, 1000 psi	40	—
Bulk Modulus. psi	21×10^6	26×10^6

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Lothar W. Koppe
San Francisco State College
San Francisco, California

INSTRUCTIONAL LEVEL: Junior High - Senior High

TITLE: An Introduction to Phase Diagrams

PRESENTATION TIME: one period

INTRODUCTION:

This unit should serve to introduce the students to alloy systems and some general characteristics of some common alloys such as the nickel-copper, lead-tin, and iron-iron carbide.

OBJECTIVES:

I have found that very few junior high school metals instructors deal with elementary topics in metallurgy. In senior high school the picture looks a little brighter, but there still needs to be an extended empahsis on the basics of the characteristics of metals. My primary aim is to demonstrate that with some very rudimentary teaching aids the instructor can bring over points which students would otherwise have difficulty in understanding.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER--RELATION WITH OTHER SUBJECTS:

Metallic alloys are similar to a new type of alloying system in which plastics are alloyed, "Kydex" is one such system in which PVC and Acrylic are combined.

USE IN INDUSTRY:

The industry depends entirely on alloys, only in certain isolated industrial application is the pure metal being used. For example, copper is used as an electrical conductor, pure tim is used for the coating of tin cans.

MATERIALS AND EQUIPMENT:

- A series of overhead projector transparencies showing photomicrographs of metals

-Phase diagram drawings for the overhead projector
-Recalesence-Decalesence teaching device
-Alloy phase demonstration device

EDUCATIONAL MEDIA:
-Transparencies for the overhead projector
-Overhead projector
-Recalesence-Decalesence apparatus
-Phase demonstration device

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

PRESENTATION:

An Introduction to the Phase Diagrams

A phase diagram is a graphic representation of the characteristics of an alloy, be it a binary, tertiary, or even more complex combination of metallic elements making up that alloy.

The simplest representation of an alloy is one in which two metallic elements are soluble in each other in any proportion, copper and nickel is one such alloy, refer to diagram no. 1. the left and right y axes represent the temperature of the material, the temperature increases from the point of origin at 0% A and B composition. The x axis represents the percentage composition of element A and B. From the point of origin element B decreases to the right from 100% to 0%, and element A decreases to the left from 100% to 0%.

If one traces the composition of 80% of alloy A and 20% of alloy B by drawing a vertical line, one finds that two diagonal lines have to be crossed at the upper portion of the diagram. The sloping line at point T1 is known as the Liquidus line above which all the metallic material is in a liquid state. If the alloy would slowly cool so that it would drop below the point T1 the alloy enters a mushy rnage which lasts between the temperatures represented by T1 and T2. Below point T2, which crosses what is known as the Solidus line, the alloy is completely hard or solid, this state usually is called a solid solution.

One might just ask why the Liquidus and Solidus lines spread from a high point at TA and converge at a lower temperature at point TB, this is probably due to the fact that each element demonstrates a certain degree of incompatability in the mushy range. This may be caused by a greater atomic activity in that temperature range and by the different melting points of the individual metals.

The Lead-Tin Binary System

An interesting difference between the copper-nickel phase diagram and the lead-tin system is that lead and tin have two restricted ranges within which each metal is completely soluble in the other. Diagram no. 2 shows the total solubility of Tin (Sn) to be about 3% between the temperature of 417° F and approximately 240° F. A similar restricted range exists at the right of the diagram for lead. This metal is approximately 18% soluble in tin between the temperature of 621° F and some temperature below the freezing point of water.

The characteristic liquidus line, which is intact in the copper-nickel phase diagram is interrupted in the lead-tin binary system. This interuption is located at a point of approximately 38% tin and 42%lead (380° F) where both liquidus and solidus lines intercept each other. This point is the lowest temperature at which an alloy combination of lead and tin will melt or solidify; this point usually is designated as the Eutectic point: which is Greek "eu" = well, and "tekein" = to melt, of "eutekos" = easily fused. It should be noted that the same mushyphase exists as in the copper-nickel phase diagram, except that the mushy phase in lead-tin is located to the left and right of the eutectic point. Below solidus line, which is horizontal at 380° F, and in the total solubility triangles at the left and right extremity of that same solidus line, the material is a complete solid.

The Iron-Iron Carbide Phase Diagram

If one examines the Iron-Iron Carbide Phase Diagram, one notices a considerable degree of complexity over the two previous systems which were examined.

This alloy system, consisting of Carbon and Iron as shown in diagram no. 3, has many of the same structures as those seen in the lead-tin system. The liquidus line is interrupted at point E (2065° F, 4.3% carbon) which is the eutectic point. Above the line BC one still has the characteristic mushy phase.

The eutectiod point, which is similar to the eutectic point, is located at J (.81% carbon at 1333° F). It should be noted that a solid exists in the area above and below this point.

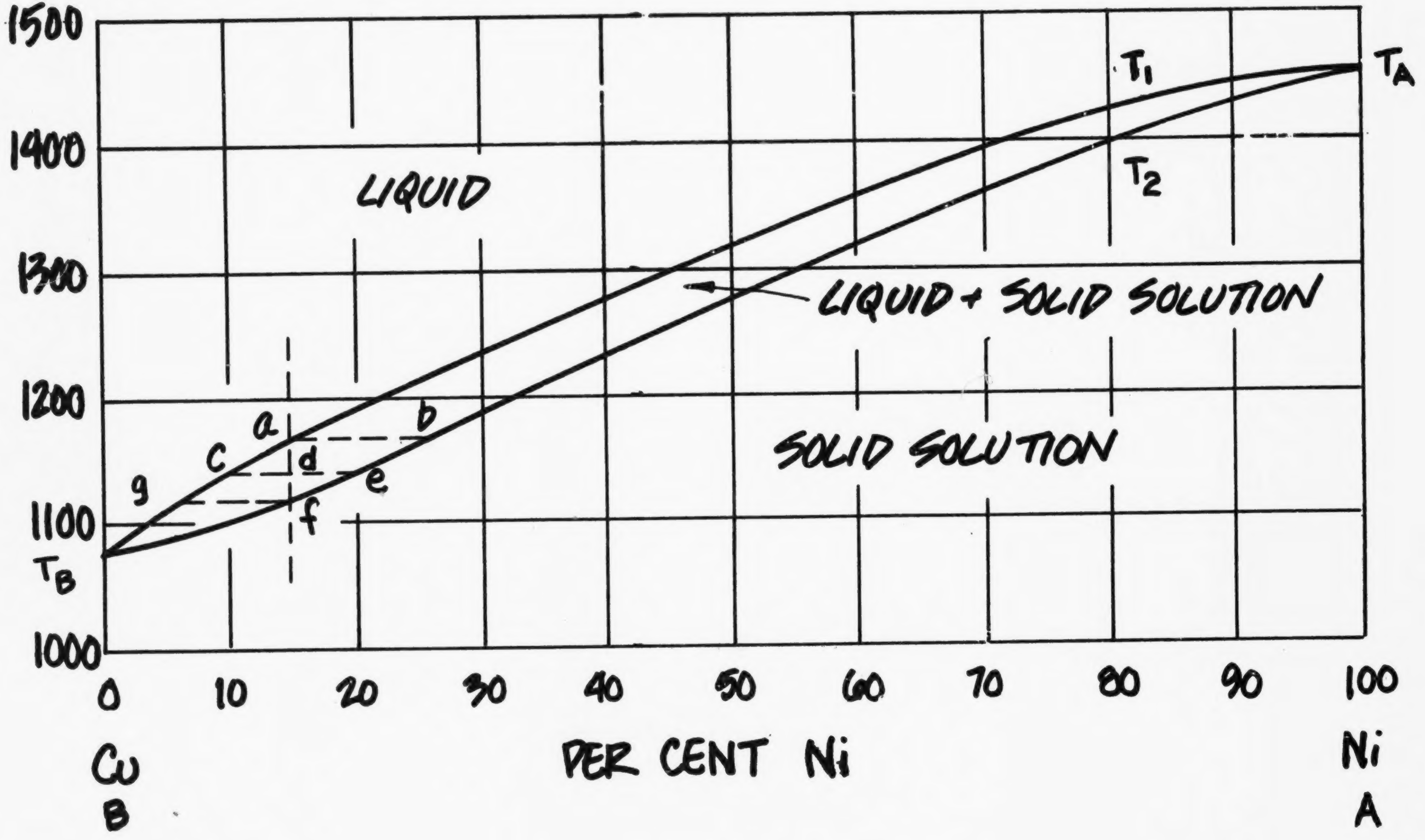
On cooling, Austenite (see micrograph 1 & 2), an interstitial (space beteeen atoms) solid solution of 8% carbon dissolved in face centered cubic iron, transforms at point J to pearlite (see micrograph 3 & 4) which is a mixture of iron carbide and ferrite having a body-centered cubic structure (see diagram 4 & 5).

Partial solubility of carbon in iron is again evident if one sights along line KJ to the left. The tiny triangle shows that approximately .025% carbon can dissolve in iron, any more carbon will simply precipitate out, giving the alloy the characteristic of a mixture rather than a solution.

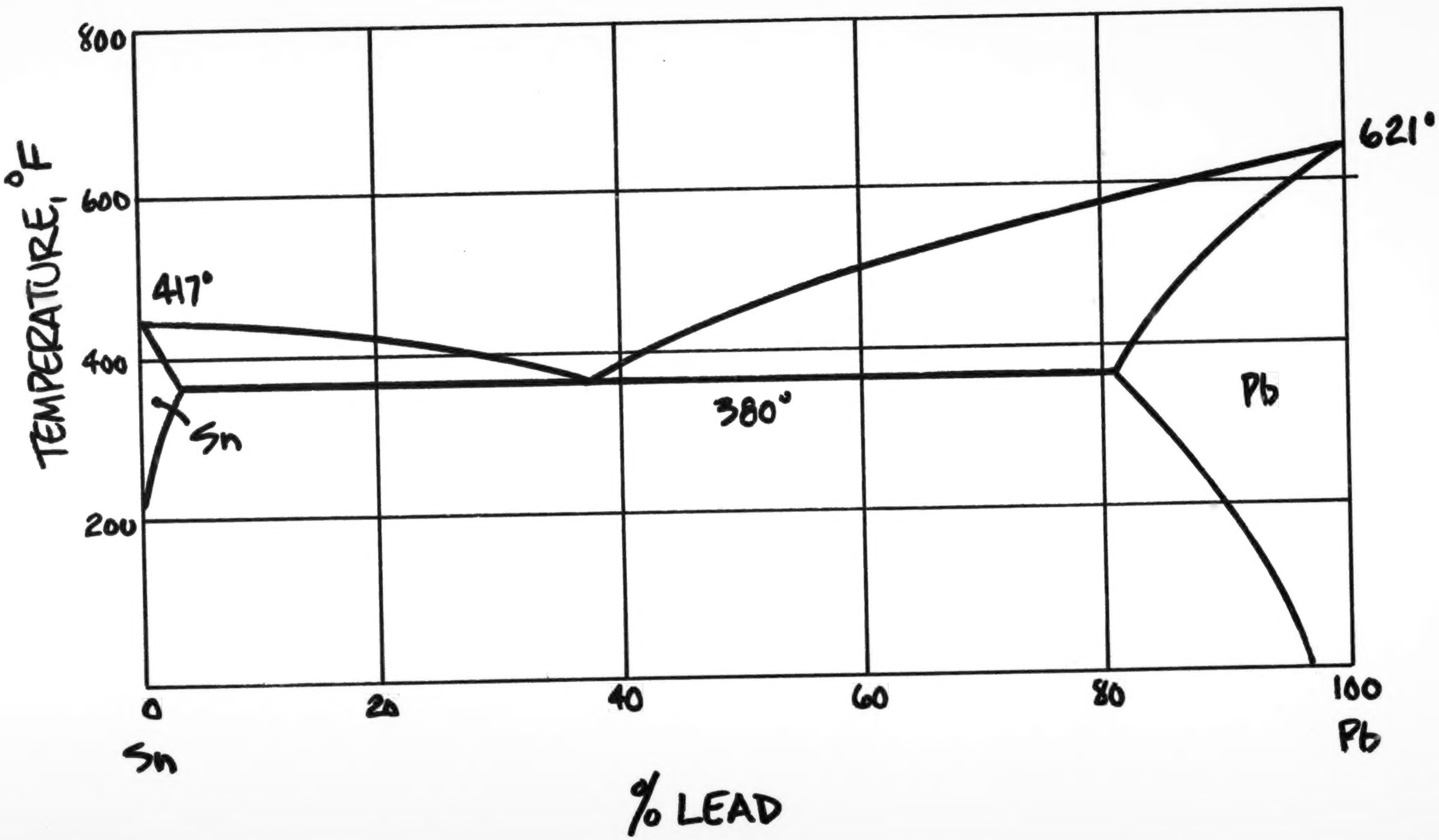
Whenever the greek letter gamma is applied, the iron constituent is in a face-centered-cubic structure, and whenever the greek letter alpha is used, it means that a body-centered cubic structure exists (see diagrams 4 & 5). The exact mechanism which changes the lattice structure is not clearly understood as yet, however this can be demonstrated dramatically by using a recalesence-decalesence teaching device. This unit can be constructed quite easily by sending a current through a thin steel or iron wire whose center is connected to an indicator (see diagram 6).

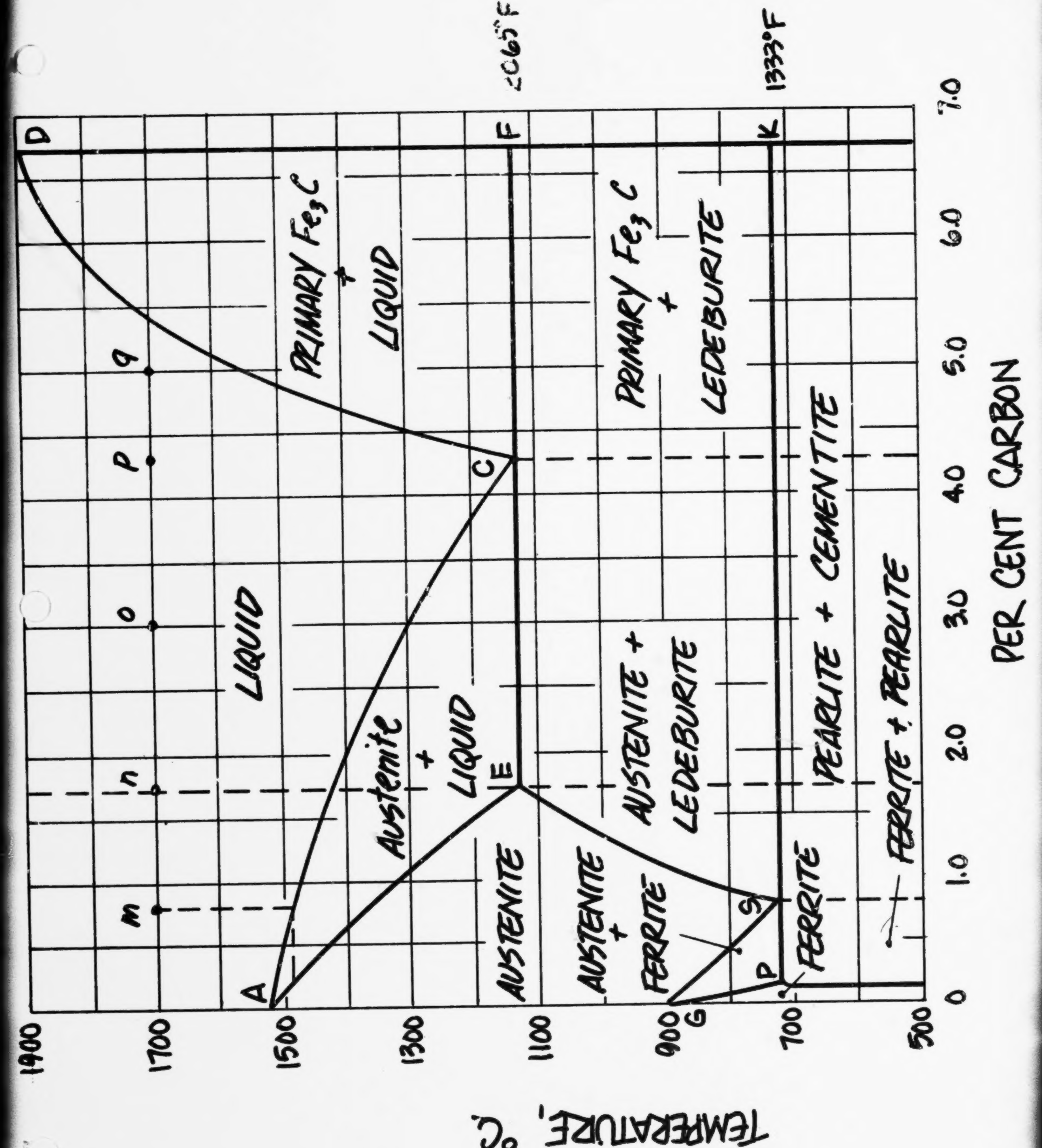
Alloy Phase Demonstration Device

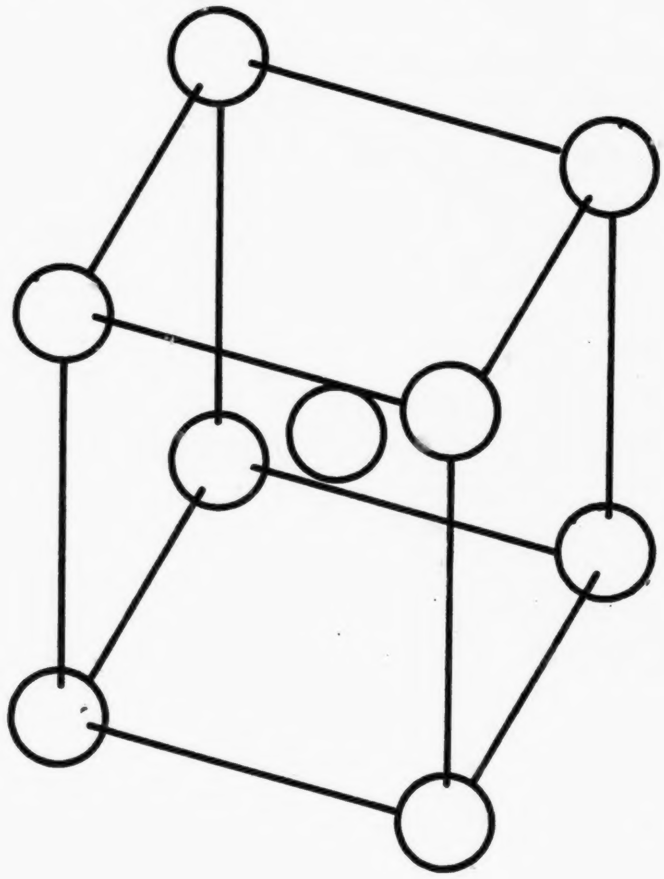
Figure 7 shows a teaching device which could help the student associate the tin-lead phase diagram with the actual alloy as it is heated and cooled. The apparatus consists of five electrically heated brass containers, each holding a different alloy composition. Of the two outside containers, one contains pure lead and the other pure tin. The middle container is filled with eutectic alloy. The whole system is teated equally and high enough so that all containers hold the liquid metal. A plunger is allowed to oscillate up and down in each of the vessels while the liquid metal cools. The rate of descent of the plungers will vary as the liquidus line is crossed on cooling. As cooling continues all plungers freeze at the same point in the metal when the solidus line is crossed. To demonstrate the physical phenomenon of the systematic slowing down of the plungers, a chart is placed behind the apparatus on which the lead-tin phase diagram has been drawn. (A patent for this device is pending).



1500
1400
1300
1200
1100
1000
T_B
T_A
T_1
T_2
LIQUID
LIQUID + SOLID SOLUTION
SOLID SOLUTION
a
b
c
d
e
f
g
0
10
20
30
40
50
60
70
80
90
100
PER CENT Ni
Cu
B
Ni
A

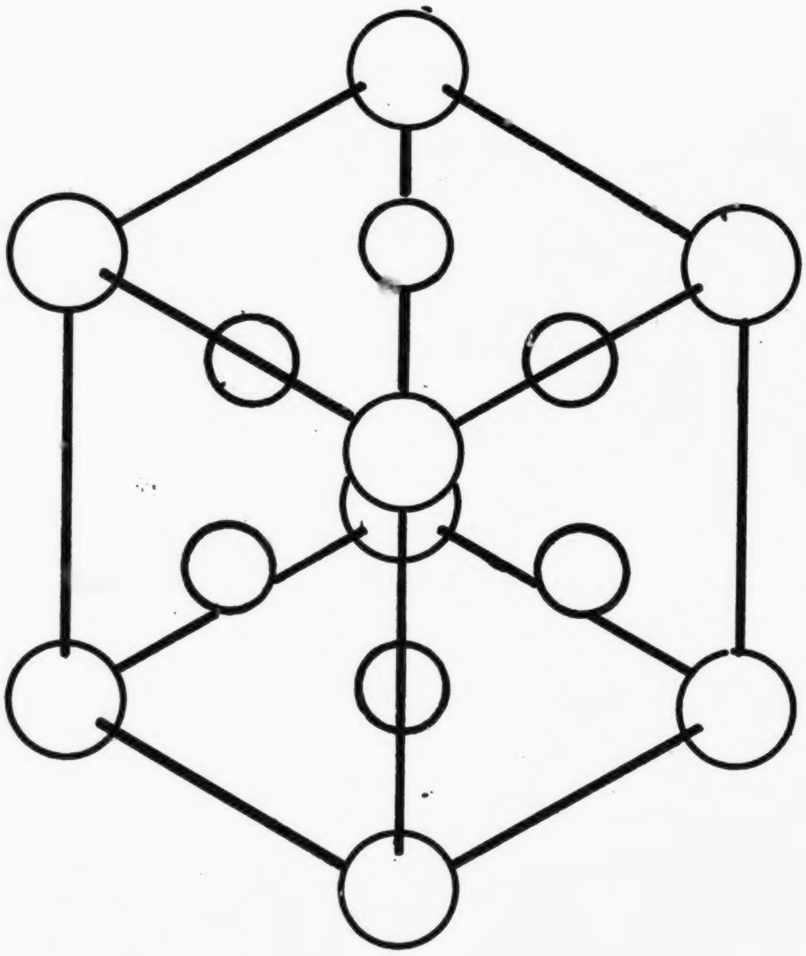

800
600
400
200
TEMPERATURE, °F
417°
Sn
380°
Pb
621°
0
20
40
60
80
100
Sn
Pb
% LEAD


TEMPERATURE, °C.
1900
1700
1500
1300
1100
900
700
500
PER CENT CARBON
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
A
C
D
E
F
G
K
P
S
m
n
o
p
q
2065°F
1333°F
LIQUID
Austenite + LIQUID
PRIMARY Fe3C + LIQUID
AUSTENITE
AUSTENITE + FERRITE
AUSTENITE + LEDEBURITE
PRIMARY Fe3C + LEDEBURITE
FERRITE
FERRITE + PEARLITE
PEARLITE + CEMENTITE



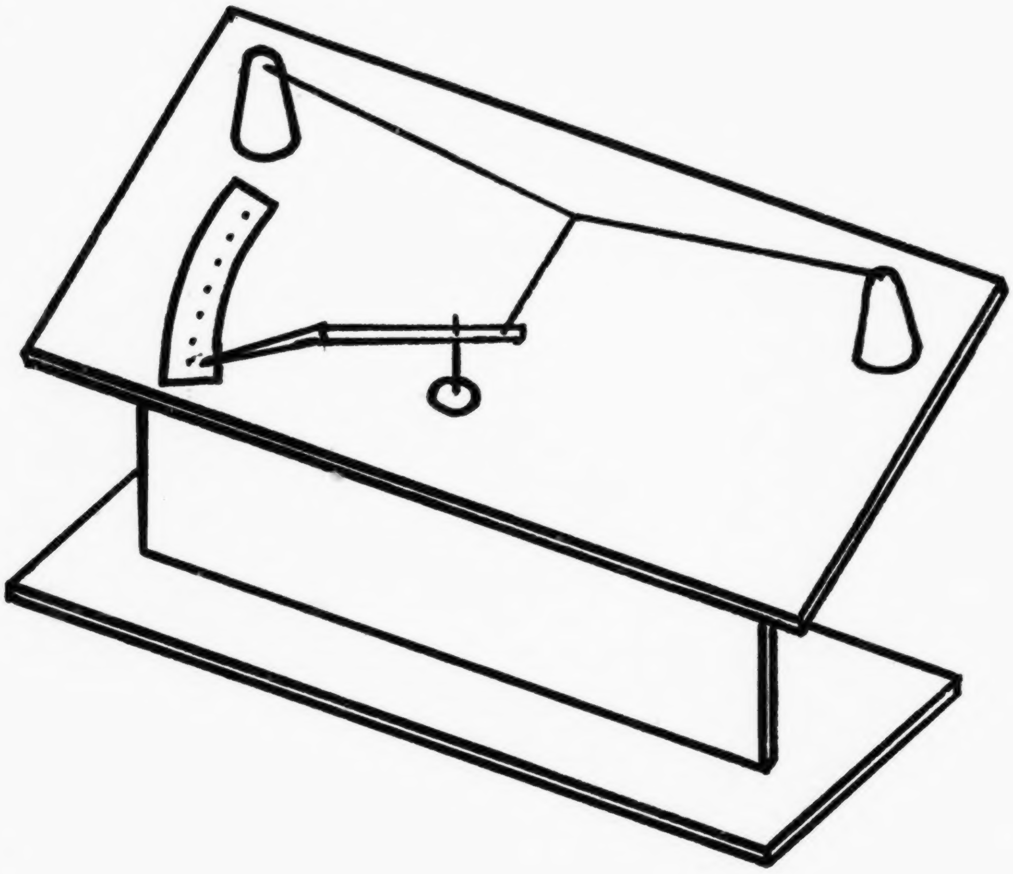
BODY
CENTERED
CUBIC α

DIAGRAM #4



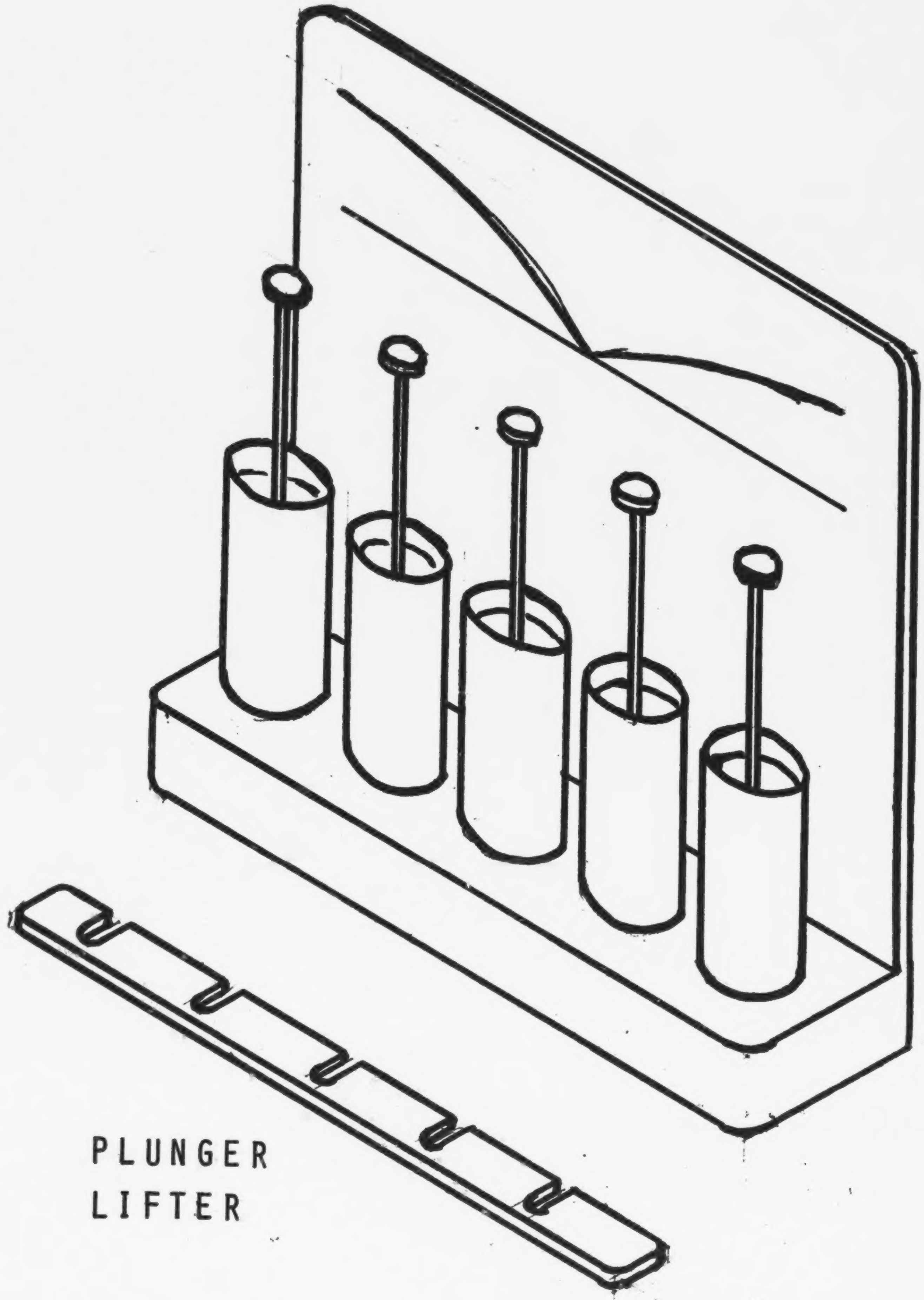
FACE
CENTERED
CUBIC γ

DIAGRAM #5



RECALESCENCE-DECLESCENCE
TEACHING APPARATUS

DIAGRAM 6


PLUNGER
LIFTER

ALLOY PHASE DEMONSTRATION DEVICE

DIAGRAM 7

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDEIS DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: W. J. Champagne
Southeastern Louisiana College
Hammond, Louisiana

INSTRUCTIONAL LEVEL: College

TITLE: Mechanical and Physical Testing of Metals

PRESENTATION TIME: 3 periods

INTRODUCTION:

Designers and engineers are constantly improving material testing methods in order to select the most suitable product for specific problems. Such problems lead to space age demands for lighter and smaller parts, coupled with economics. This has caused the gap of weight-size-cost limitation between failure and success to reduce considerably.

The testing methods outlined in this unit are standardized. If equipment is not available, teachers could set up their own standards and apparatus to meet specific needs and limitations. Several references listed in this unit are excellent sources for non-standardized testing equipment and procedure ideas. American Society for Testing and Materials manuals in particular are excellent sources for ideas and also for modifying experimentation.

OBJECTIVES:

The purposes of this unit are to:

1. Guide student learning so that he will become aware of the various common industrial methods of mechanical and physical testing of metals.
2. Provide students with sufficient testing data so that the student can initiate, plan, perform and report results of an experiment in an organized manner.
3. Provide opportunities for students to perform various tests prior to formal planning so that initial ideas can be more meaningful.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:
Physics, Chemistry, Math, English-report organization and reporting results

USE IN INDUSTRY:

Information for designing
Successful prediction of product performance
Quality and safety control

MATERIALS AND EQUIPMENT:

Adequate supply of a variety of popular construction alloy metals for specimen preparation.

Universal tester, suitable for tensile, compression, bending, beam transverse loading, shear, or separate machine for performing these tests.

Calibration instruments and supplies for alignment of equipment.

Tool panel containing screwdrivers, wrenches, pliers, etc., plus an adequate supply of instruments, such as extensometers, micrometers, claipers, dividers, measuring rules--regular and metric, etc.

Hardness tester with all types of penetrators available.

Metal specimen polisher and an adequate supply of abrasives.

Specimen mounting and etching supplies.

Microscope.

EDUCATIONAL MEDIA:

Overhead transparencies
Handouts
Lecture-discussion
Demonstrations
Experimentation

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Clear plastic guards around machinery while loading specimen.

Eye protection programs (shields, goggles) while etching, grinding, etc.

Safety instruction on the use of testing equipment and handling of acids.

PRESENTATION:

I. Introduction
    A. Identification of Unit
    B. Uses in Industry
    C. Future
II. Testing Machines
    A. Definition - A mechanical device for applying a load or force to a specimen.

- B. Standard methods of verifying testing machines
  - 1. Load
  - 2. Permissible accuracy variations
  - 3. Error specifications
    - a. Percentage of error
    - b. Correction
- C. Calibrations devices
  - 1. Standard weights
  - 2. Proving levers
  - 3. Equal-arm balance
  - 4. Elastic calibrations devices
- D. Gravity corrections
- E. Method of applying load
- F. Selection of test loads
- G. Eccentric loading

III. Mechanical tests for metals

- A. Tension
  - 1. Set-ups
  - 2. Specimen
    - a. Selection
    - b. Preparation
  - 3. Apparatus and operations
    - a. Loading systems
      - (1) Screw power
      - (2) Hydraulic
    - b. Loading procedure
      - (1) Axially
      - (2) Grip alignments
      - (3) Speed of testing
  - 4. Stress-strain diagram
    - a. Types
      - (1) Engineers
      - (2) True
    - b. Measuring elongation
      - (1) Autographic diagram
      - (2) Divider method
      - (3) Extensometer
    - c. Parts or areas of diagram
      - (1) Proportional stress-strain area
        - (a) Modulus
        - (b) Elastic point-range
      - (2) Plastic range
        - (a) Yield point-yield strength
          - i. Extension under load
          - ii. Offset method
        - (b) Work hardening area

        (c) Ultimate strength
        (d) Breaking strength
    5. Tensile Strength

$$\text{Tensile strength} = \frac{\text{Maximum load}}{\text{Original C.S.A.}}$$

    6. Elongation
        a. Fit severed ends together
        b. Measure elongation
        c. Express as percentage increase and original gage length

$$\text{Percent elong.} = \frac{\text{Final length - original length}}{\text{Original length}} \text{X } 100$$

    7. Reduction of area
        a. Fit severed ends together
        b. Measure area reduction
        c. Express as percentage decreased and original C.S.A.

$$\text{Percent reduction} - \frac{\text{Final CSA - original CSA}}{\text{Original CSA}} \text{X } 100$$

B. Transverse rupture-brittle materials
    1. Specimen preparation
    2. Alignment of specimen
    3. Load application
    4. Strength calculation

$$\text{Modulus of rupture} = \frac{3\,P\,L}{2\,bd^2}$$

P = pressure
L = distance between bearing points
b = width of beam
d = thickness of beam

C. Bend test for weld ductility
    1. Loading specimen
    2. Usefulness
    3. Severity of bend
    4. Aging specimen
    5. Preparation of specimen

- 6. Gage lines
- 7. Procedure for testing
- 8. Soundness and fusion examination
  - a. X-rayed bends
  - b. Lack of fusion
  - c. Cracks
  - d. Porosity
- 9. Measurement of fiber elongation
- 10. Reporting results
  - a. Specimen dimensions
  - b. Gage length used for elongation measurement
  - c. Elongation
  - d. Size and description of cracks or defects, if any
  - e. Angle of initial bend.
- D. Hardness
  - 1. Definition
    - a. Resistance to penetration
    - b. Quick approximation of tensile test
  - 2. Brinell test
    - a. Verification of equipment
    - b. Definition
    - c. Apparatus
      - (1) Machine
      - (2) Brinell balls
    - d. Brinell hardness numbers
      - (1) Chart
      - (2) Formula

$$HB = \frac{2P}{\pi D \left(D - \sqrt{D^2 - d^2}\right)}$$

P = applied load, kilogram force
D = diameter of the ball, mm.
d = mean diameter of the impression

- e. Measuring microscope
- f. Test specimen
  - (1) Thickness
  - (2) Finish
- g. Conversion to other hardness scales or tensile values
- h. Reporting
  - (1) The brinell number
  - (2) Conditions of hardness determination
    - (a) Load
    - (b) Diameter of ball
    - (c) Loading time

      (3) Type of ball used
3. Rockwell
   a. Description
      (1) Regular
      (2) Superficial
   b. Verification and calibration
      (1) Test blocks
      (2) Precautions
      (3) Vibrations
   c. Apparatus
      (1) Depth of penetration
      (2) Penetrator
         (a) Diamond cone-brale
         (b) Stell ball
      (3) Numbering system
      (4) Loads applied
         (a) Minor
         (b) Major
      (5) Reading hardness number
      (6) Hardness scales
   d. Test specimen preparation
      (1) Sizes
      (2) Surface conditions
   e. Reporting hardness
4. Other hardness test methods
   a. Vickers-diamond pyramid penetrator
   b. Shore Scleroscope
      (1) Rebound height of small diamond hammer
      (2) Definite weight
      (3) Visual observation or recording dial
   c. Knoop

E. Impact
   1. Definition-description
   2. Test specimen
      a. Selection
      b. Size and shape of specimen
         1. Charpy
         2. Izod
      c. Preparation
      d. Aging of specimen
   3. Apparatus--types of machines
      a. Charpy
      b. Izod

F. Compression
   1. Definition-decription
   2. Data obtainable

a. Yield strength
b. Yield point
c. Modulus of elasticity
d. Compressive strength (some materials)
   (1) Brittle materials
   (2) Ductile materials

3. Specimens
   a. Solid cylindrical form
      (1) Short
      (2) Medium-length
      (3) Long
   b. Rectangular or sheet type
   c. Preparation
      (1) Machined latteral surfaces
      (2) Not vary in diameter more than .0002 in.
   d. Gage length
   e. Measurement
   f. Cleaning
4. Testing speed
5. Determining yield strength-point
   a. Off-set method
   b. Sharp knee in curve
   c. Autographic-diagram
6. Apparatus
   a. No critical instability within its loading range
   b. Platens stable
   c. Bearing blocks
7. Determination of compressive strength
   a. Shattering fracture
   b. Ductile material failure

G. Creep
   1. Definition
   2. Continuous deformation under constant load
   3. Unit stresses below elastic limit
   4. Normal temperature
   5. Elevated temperature
   6. Testing procedure
   7. Reporting
      a. Creep strength
      b. Stress rupture strength

H. Shear
   1. Definition
   2. Accuracy of test
   3. Testing set-up, double shear
   4. Reporting

$$\text{Shear Strength} = \frac{P}{2\ CSA}$$

I. Fatigue
1. Definition
2. Repeated stress cycles
3. Alternating loading
4. Fatigue failure starts
    a. Imperfections
    b. High stress area
    c. Holes through members
    d. Notches
    e. Internal flaws-corrosive attack on grain boundaries
5. Testing set-up
6. Reporting

IV. Physical test for metals
A. Modulus of elasticity-tensile or compression (Young's modulus)
1. Definition-Hook's law
2. Accuracy importance
3. Apparatus
    a. Calibrated dead weights
    b. Machines
    c. Extensometer
    d. Alignment devices
4. Specimens
    a. Selection and preparation
    b. Dimensions
5. Testing procedure
    a. Measurement of specimens
    b. Alignment
    c. Simultaneous notation of stress and strain
    d. Testing speed
    e. Temperature
6. Calculations

$$E \text{ or Young's Modulus} = \frac{\text{Stress}}{\text{Strain}}$$

B. Shear modulus-modulus of rigidity
1. Definition
2. Apparatus-torque deformation
    a. Machine
        (1) Calibrated torque range
        (2) Accuracy of range

- b. Grips
- c. Twist gages

3. Specimens
   - a. Selection and preparation
   - b. Dimensions
4. Procedure
   - a. Measurement
   - b. Alignment
   - c. Torque and angle of twist
   - d. Speed of test
   - e. Temperature
5. Reporting

$$G = \frac{\text{Shear stress}}{\text{Shear strain}}$$

C. Poisson's ratio

1. Definition (ratio determined from tension tests of structural materials)
2. Apparatus
   - a. Load
   - b. Extensometers
   - c. Alignment devices
3. Specimens
   - a. Selection and preparation
   - b. Dimensions
4. Procedure
   - a. Measurement
   - b. Alignment
   - c. Speed of testing
5. Reporting

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Axial strain}}$$

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:
Experimentation assignments
Demonstrations

UNIT EVALUATION:
Written exam on content
Technical reports
Oral and performance of assigned experiments

DEFINITION OF TERMS:

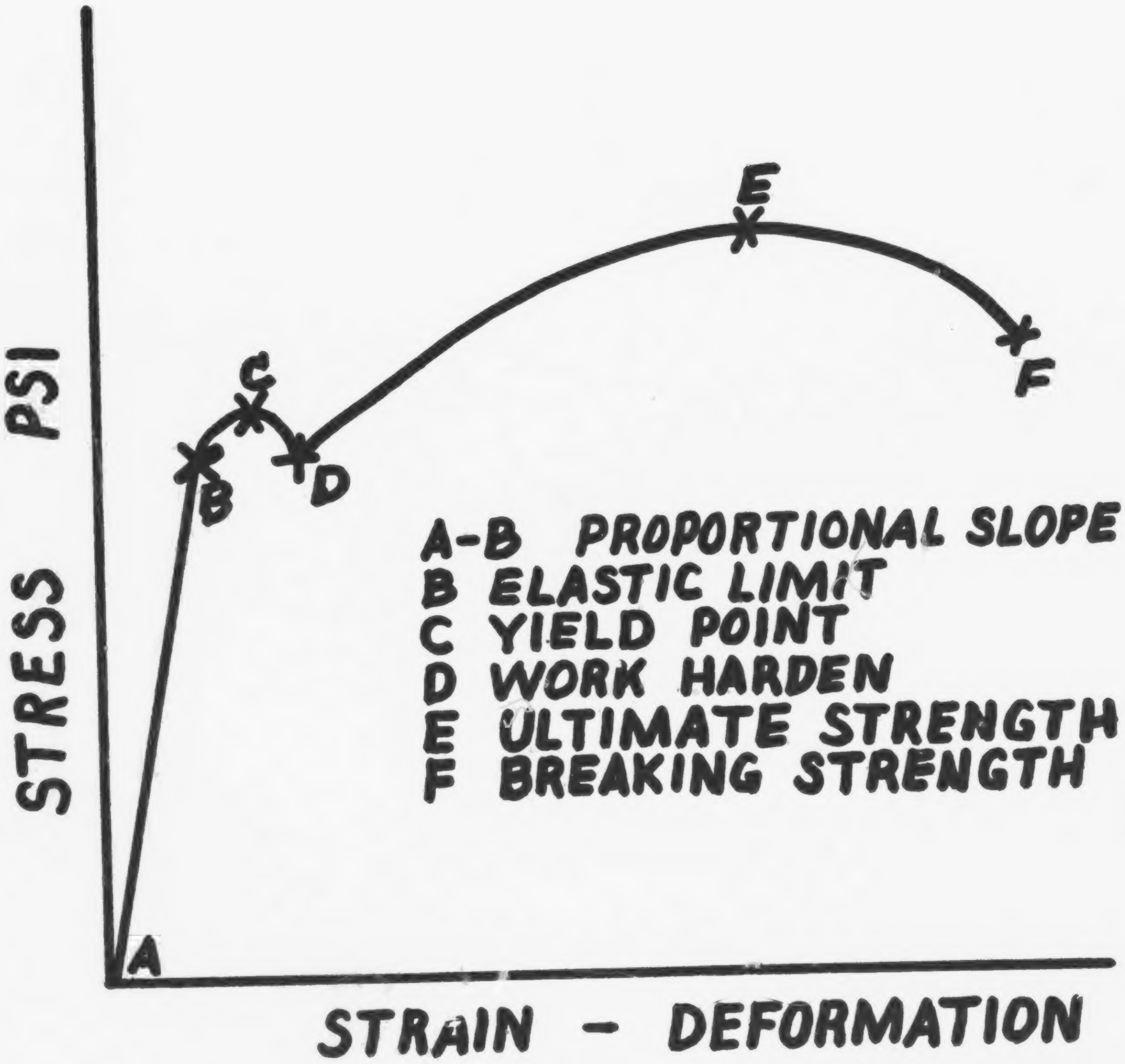
1. Breaking strength - Point at which specimen pulled breaks.
2. Calibration devices - Standards for setting and correcting inaccuracies.
3. Compressive stress - Forces directed toward the plane on which they act - compressing force.
4. Ductility - Plastic deformation before fracture.
5. Elastic deformation - Below plastic deformation - material will return to its original shape and dimensions.
6. Extensometer - Linear measurement of deformation device.
7. Hook's law - Stress is proportional to strain
8. Load - Stress being applied by the machine measured in pounds or kilograms.
9. Mechanical properties - Elastic and inelastic reaction when force is applied.
10. Necking - Localized reduction of the cross sectional area of a specimen during loading.
11. Plastic deformation - Permanent deformation without failure - material will not return, elastically, to its original size and shape.
12. Poisson's ratio - Ratio of the lateral strain to the axial strain.
13. Proportional limit - That part of the stress-strain curve below or at the elastic point where stress and strain cease to be proportional.
14. Shear modulus - Ratio of shear stress to corresponding shear strain for shear stresses below the proportional limit in shear of a material.
15. Shear stress - The stress component tangential to the plane on which the forces act.
16. Strain - Change in unit length as a result of an applied force usually expressed in inches per inch, centimeters per centimeters, etc.
17. Stress - Intensity of the internal force that tend to keep the specimen from pulling apart - expressed in force per unit of area.
18. Testing machine - A mechanical system designed to apply a controlled load to a specimen.
19. Tensile stress - Forces directed away from the plane on which they act - pulling force.
20. Tortional stress - The shear stress on a transverse cross section resulting from a twisting action.
21. Ultimate strength - Maximum load a specimen will take before a decrease in pressure or force occur.
22. Young's modulus - ratio of normal stress to corresponding strain for tensile or compressive stresses below the proportional limit of the material.

23. Yield point - Stress and strain cease to be proportional. Strain increases with little or no increase in stress.

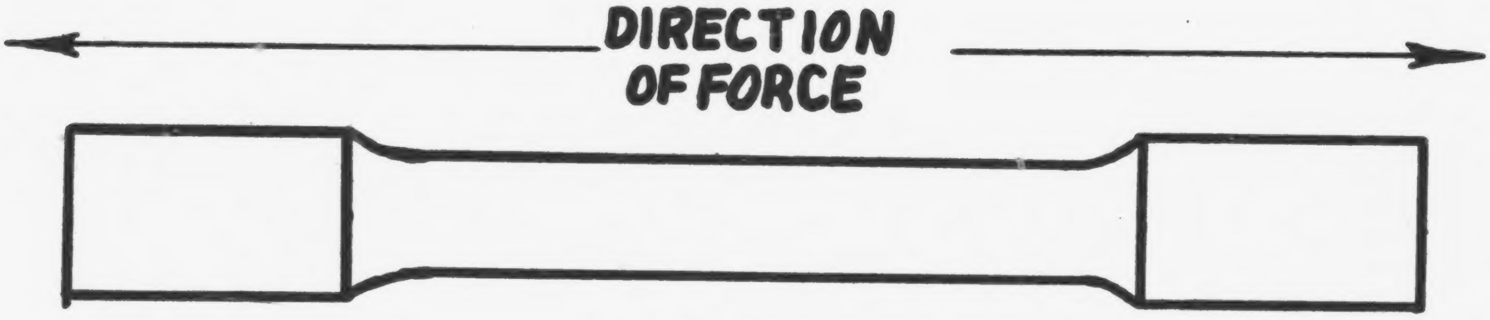
24. Yield strength - Assigned strain value for brittle material.

REFERENCES:

1. American Society for Testing and Materials, 1967 Book of Standards, Part 31, Physical and Mechanical Testing of Metals-Metallographic, Nondestructive Testing, Fatigue, Effect of Temperature: Philadelphia, Pennsylvania.
2. Cernica, John N., Strength of Materials, Holt, Rinehart and Winston, Inc., New York: 1966.
3. Earl, Arthur W., Experiments with Materials and Products of Industry, McKnight and McKnight Publishing Company.
4. Experiments and Instructional Units for Industrial Materials as an Integrated Part of the Industrial Arts, Prepared by Participants of the 1967 NDEA Institute, Title XI, San Jose State College, San Jose, California.
5. Moore, Harry D., and Donald R. Kibbey, Manufacturing Materials and Processes, Richard D. Irwin, Inc., Homewood, Illinois, 1965.
6. Samans, Carl H., Metallic Materials in Engineering, The McMillan Company, New York: 1963.
7. Umowski, Joseph S., Ferrous Metallurgy Laboratory Manual, American Technical Society, 1960.



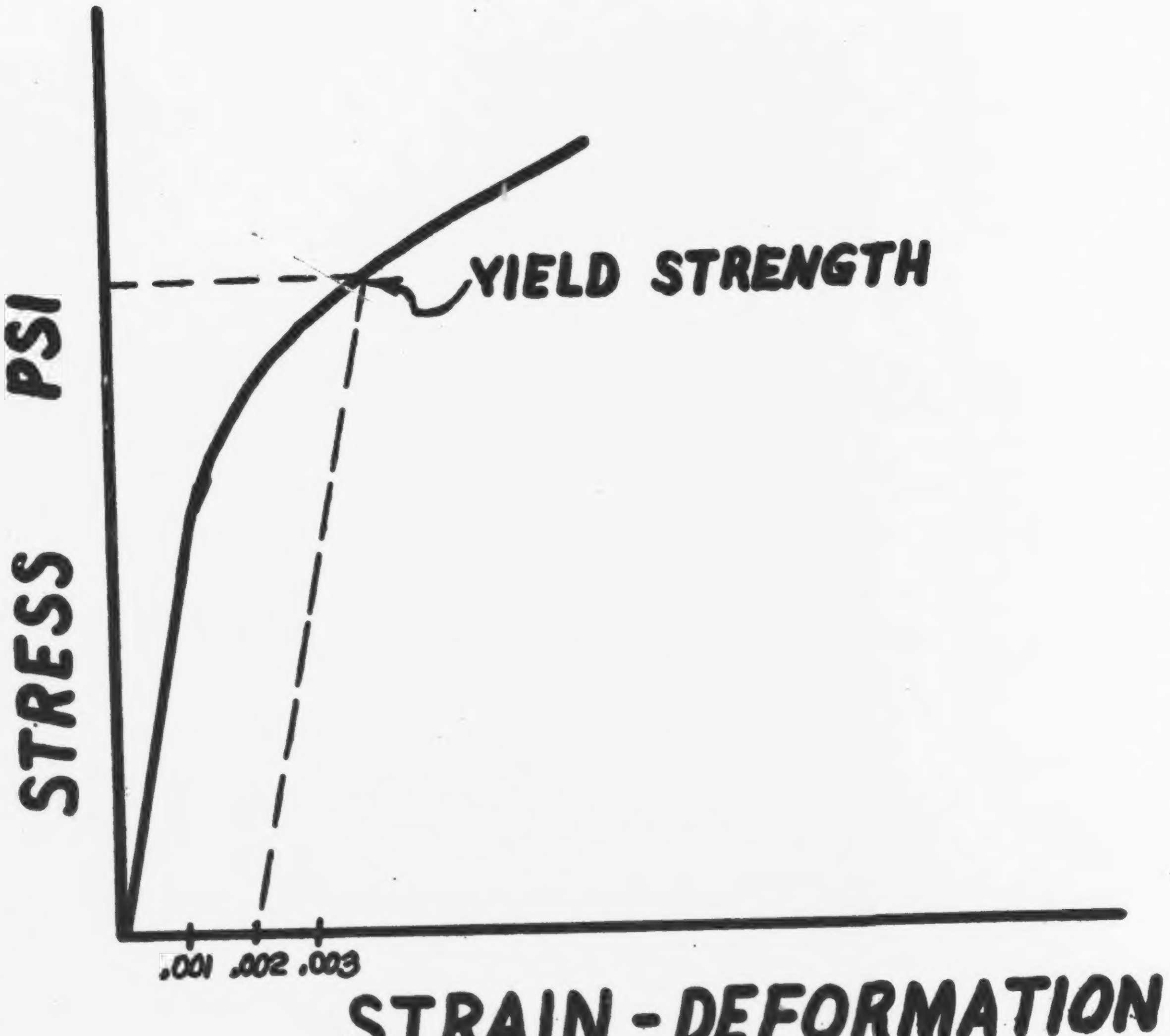
STRESS-STRAIN DIAGRAM OF A DUCTILE MATERIAL


DIRECTION OF FORCE

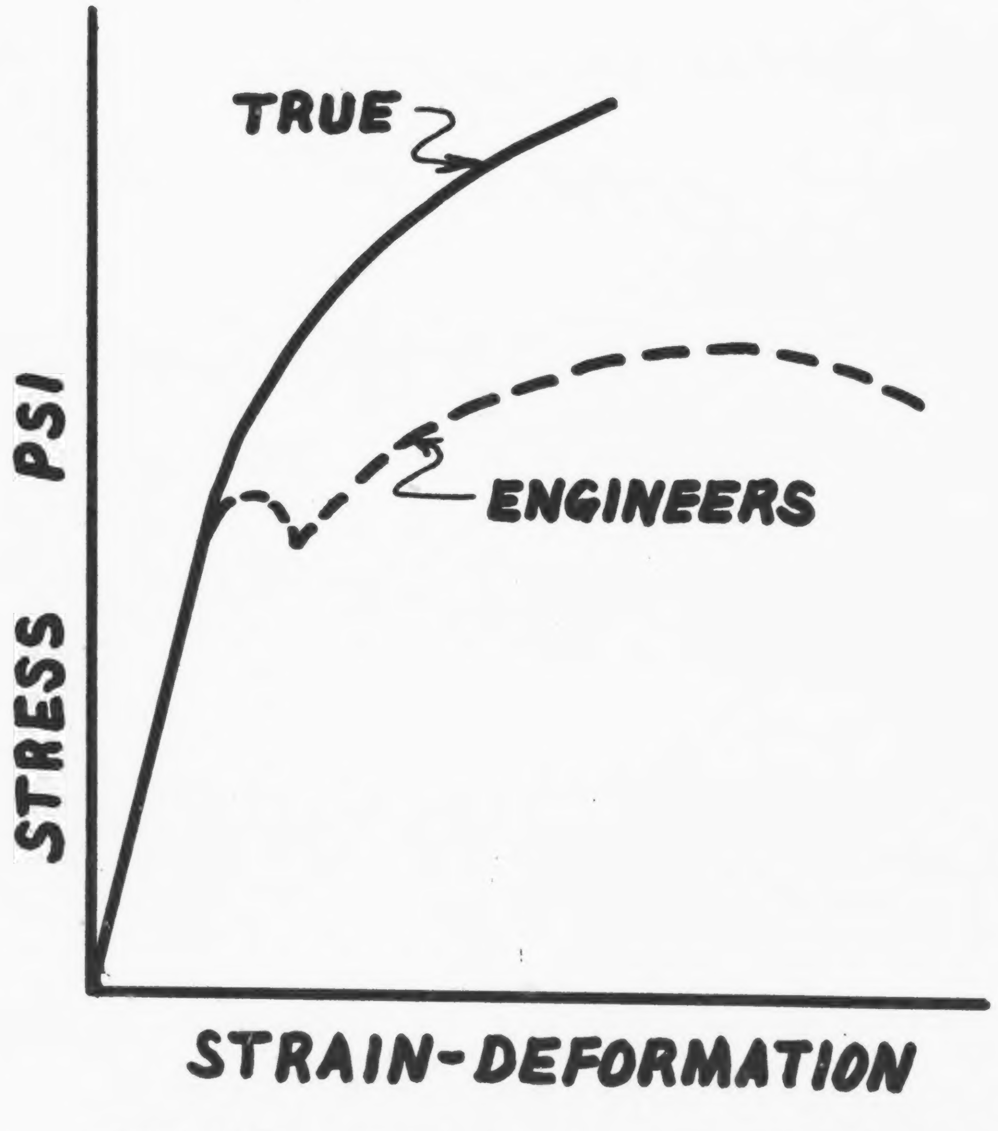
TENSILE SPECIMEN

THREADED OR PLAIN

FLAT-ROUND-OR-RECTANGULAR



STRESS-STRAIN DIAGRAM
OF A BRITTLE MATERIAL



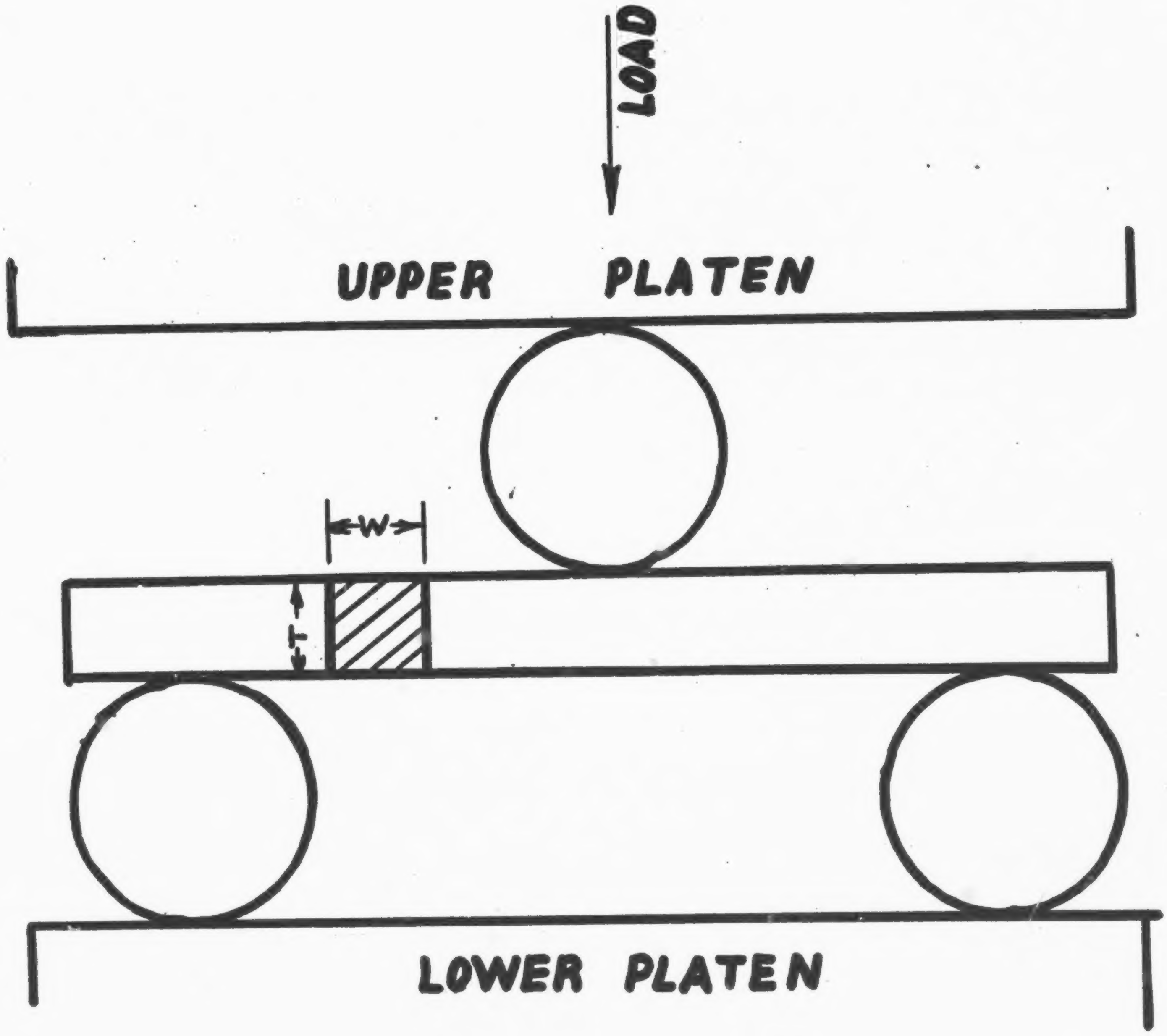
TRUE STRESS-STRAIN
DIAGRAM

4

$$\text{TEN. ST.} = \frac{\text{MAX. LOAD}}{\text{ORIG. C.S.A.}}$$

$$\%\ \text{ELONG.} = \frac{\text{FINAL LENGTH} - \text{ORIG. LENGTH}}{\text{ORIG. LENGTH}} \times 100$$

$$\%\ \text{C.S.A. RED.} = \frac{\text{FINAL C.S.A.} - \text{ORIG. C.S.A.}}{\text{ORIG. C.S.A.}} \times 100$$

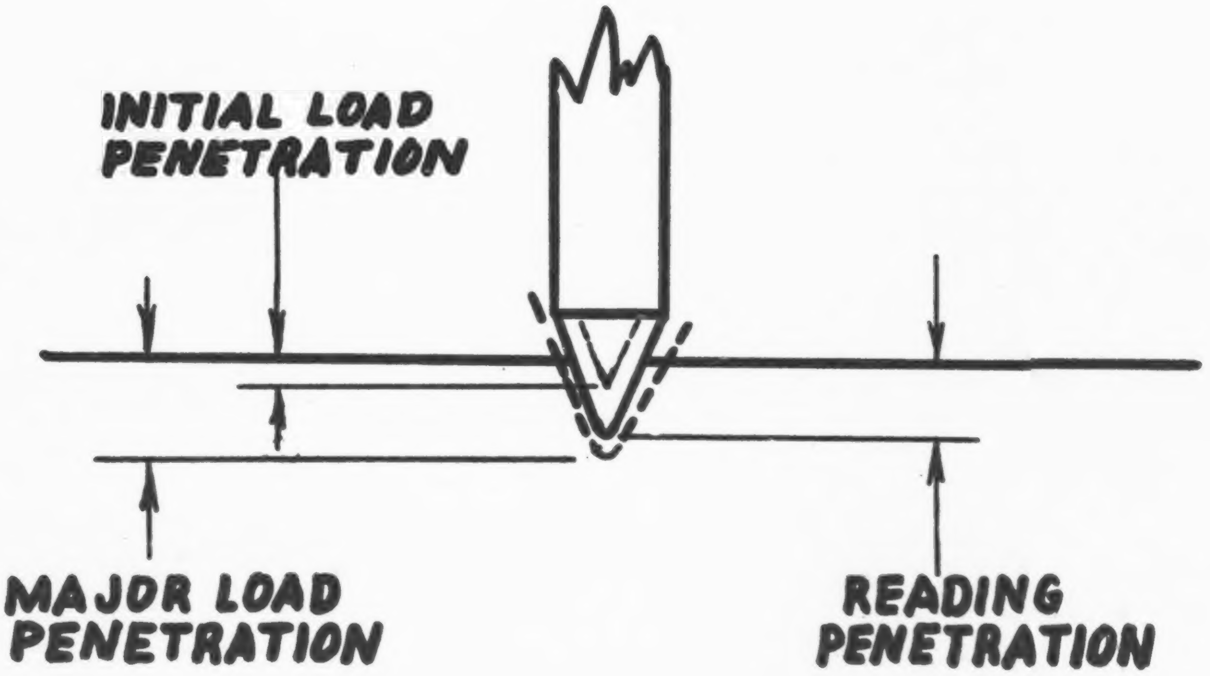

LOAD
UPPER PLATEN
W
T
LOWER PLATEN

TRANSVERSE RUPTURE

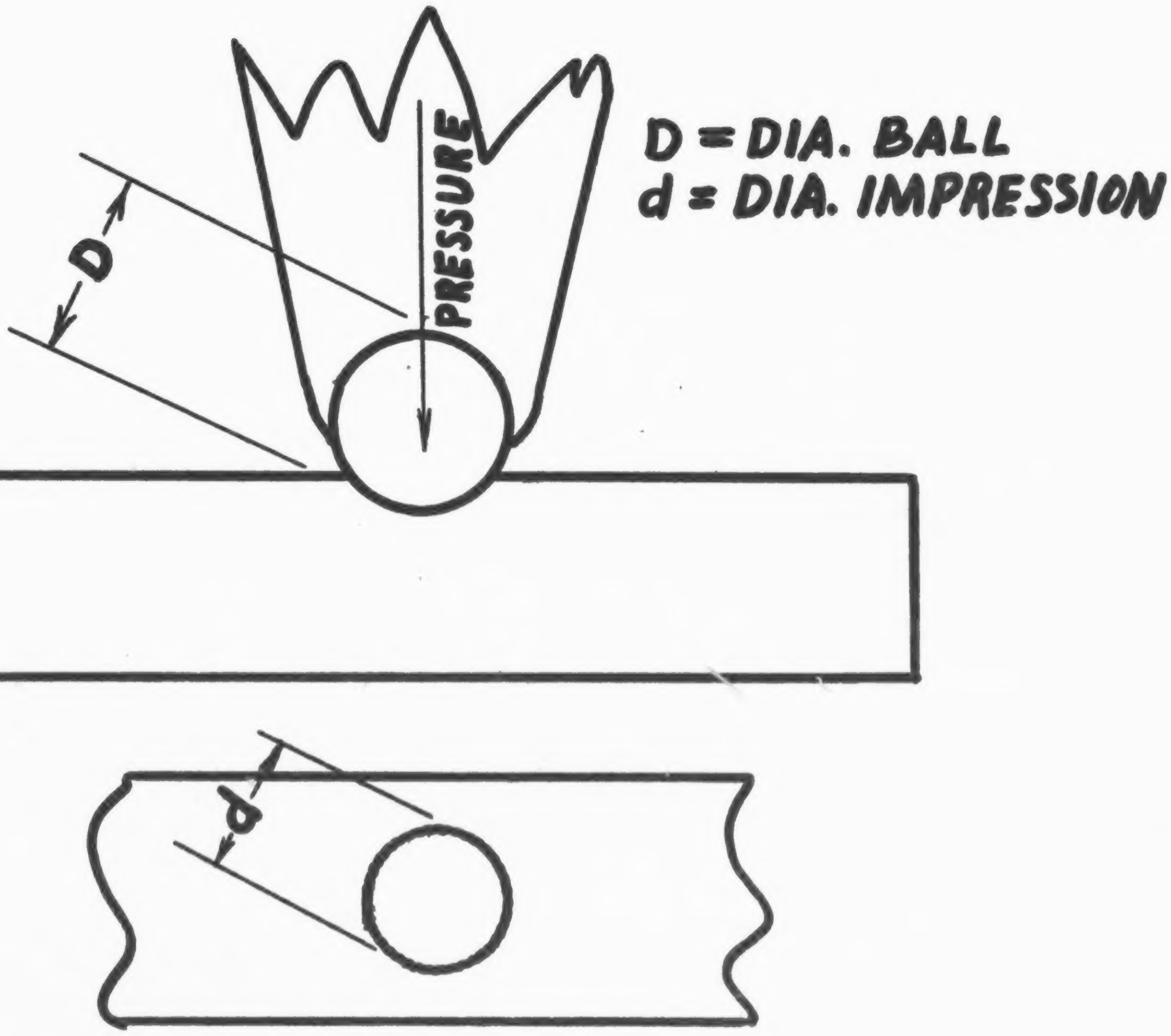
7

$$\text{MODULUS OF RUPTURE} = \frac{3\,PL}{2\,bd^2}$$

P = LOAD PRESSURE
L = DISTANCE BETWEEN SUPPORTS
bd = C. S. A OF SPECIMEN

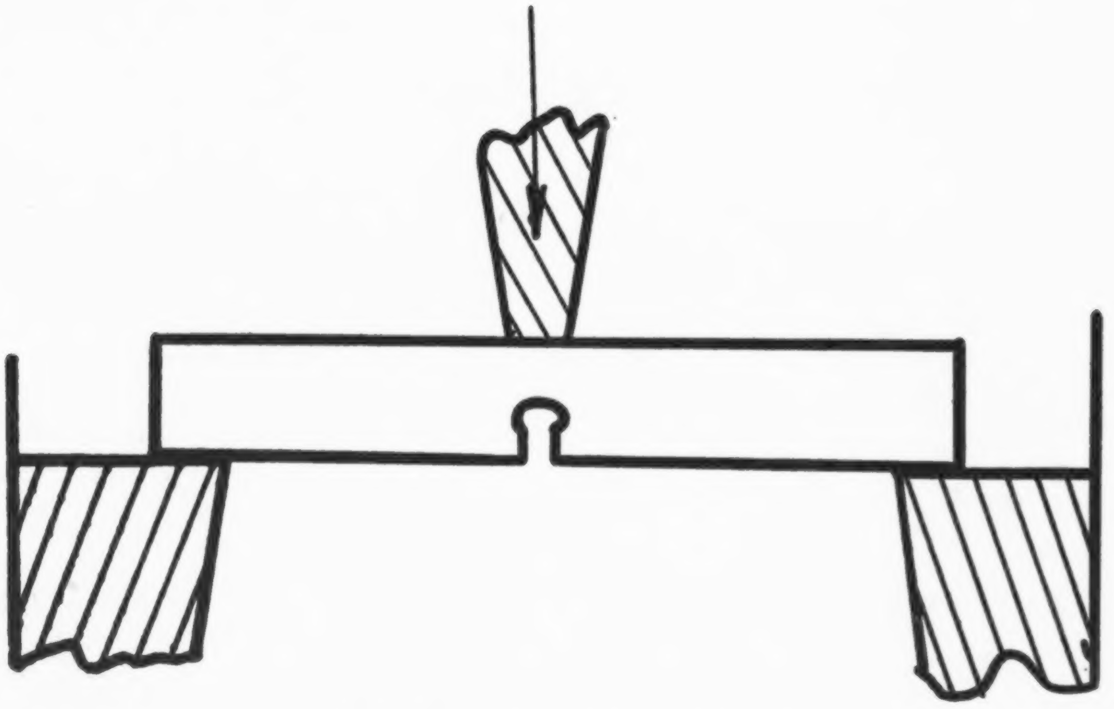

INITIAL LOAD PENETRATION
MAJOR LOAD PENETRATION
READING PENETRATION

ROCKWELL HARDNESS

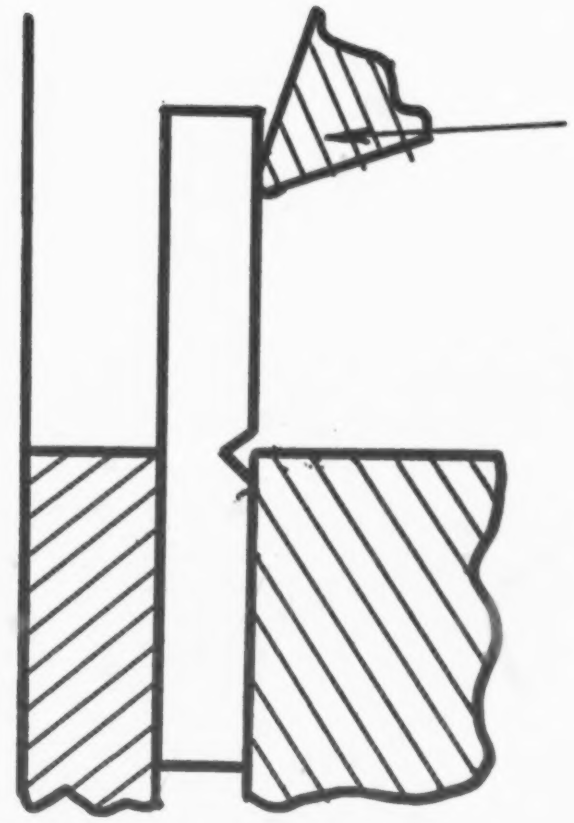

PRESSURE
D
d
D = DIA. BALL
d = DIA. IMPRESSION

BRINELL HARDNESS

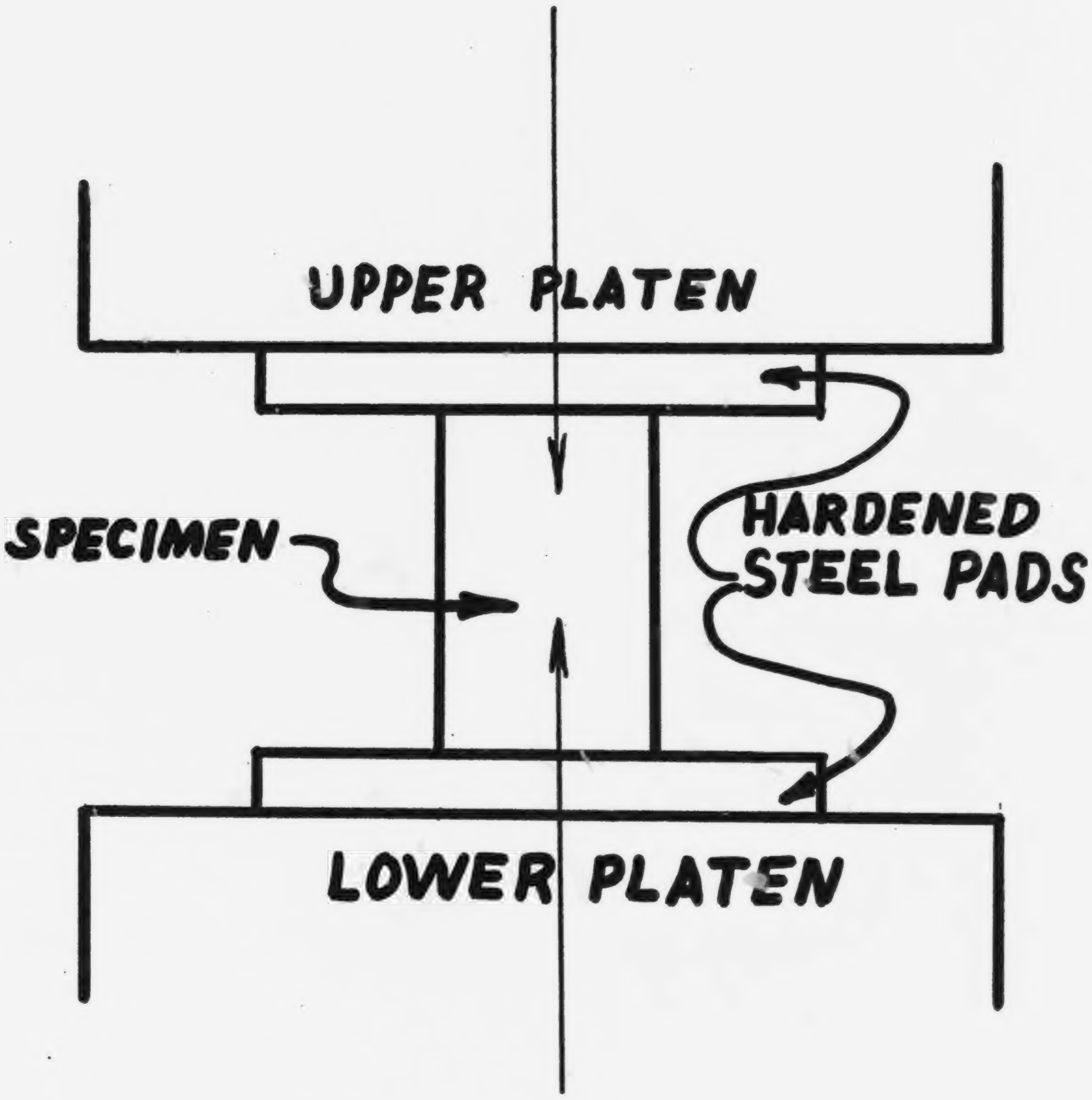
$$BHN = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$



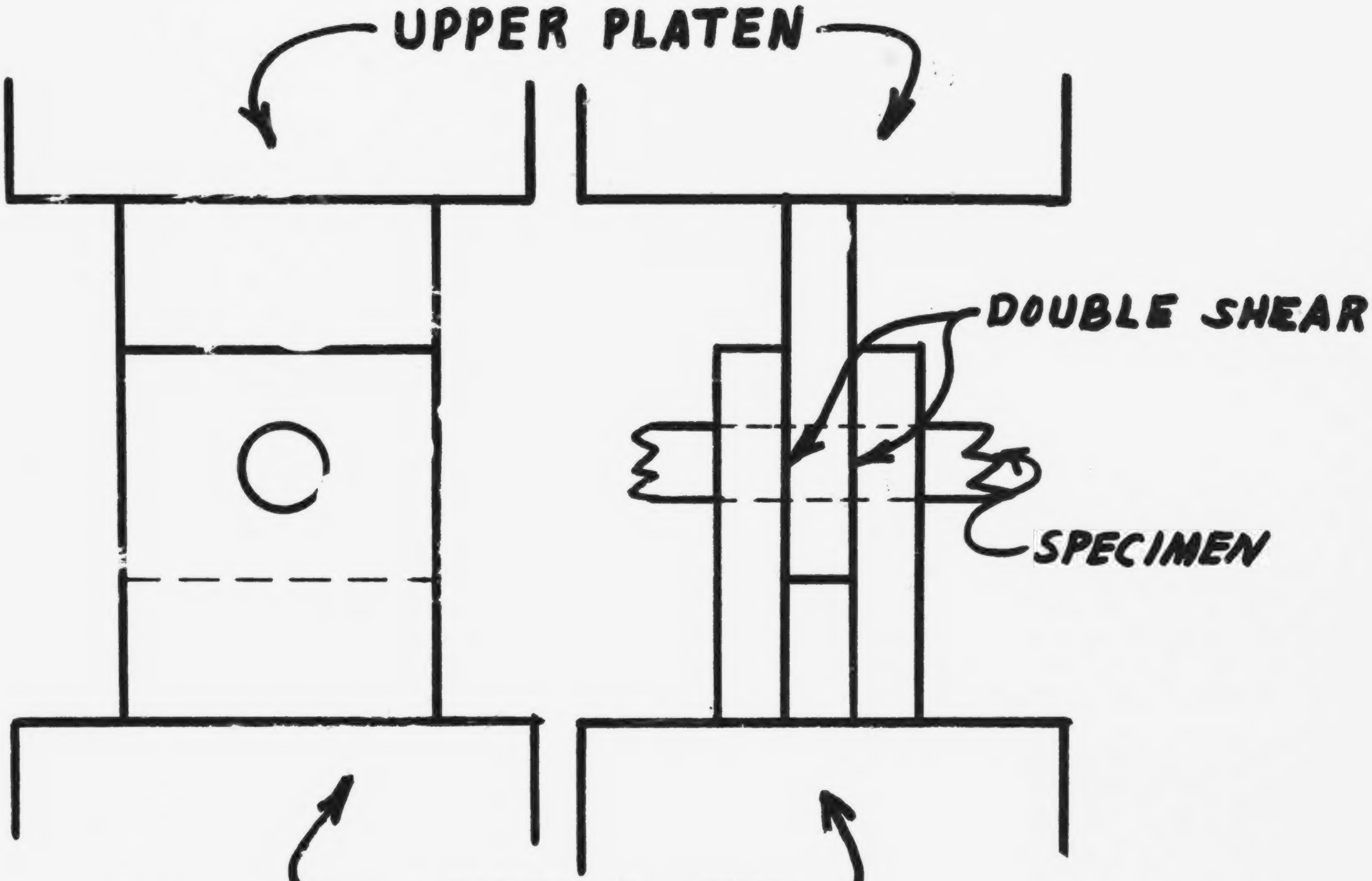
CHARPY IMPACT



IZOD IMPACT


UPPER PLATEN
SPECIMEN
HARDENED STEEL PADS
LOWER PLATEN

COMPRESSION TEST


UPPER PLATEN
DOUBLE SHEAR
SPECIMEN
LOWER PLATEN

SHEAR TEST

$$\text{SHEAR ST.} = \frac{P}{2\ \text{C.S.A.}}$$

$$\text{MODULUS OF ELASTICITY} = \frac{\text{STRESS}}{\text{STRAIN}}$$

$$\text{SHEAR MODULUS} = \frac{\text{SHEAR STRESS}}{\text{SHEAR STRAIN}}$$

$$\text{POISSONS RATIO} = \frac{\text{LATERAL STRAIN}}{\text{AXIAL STRAIN}}$$

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Arthur E. Muller
Stout State University
Menomonie, Wisconsin

INSTRUCTIONAL LEVEL: College

TITLE: Microscopic Examination of Joint Interfaces: Welded, Brazed, Soldered, and Sintered

PRESENTATION TIME: 1 to 2 hours

INTRODUCTION:

Being able to see what has occured at braze welded, soldered, welded and sintered joint interfaces will make the accomplishment of the process more easily understood. Observable defects will also verify the need for corrections in technique or material selection. Some students have difficulty believing that a sound joint may be made without melting both joint interface materials. Viewing the final results should be a clincher to those who are unwilling to accept an out of the book explanation.

OBJECTIVES:

To show the student:
- What a joint looks like "inside"
- What has occured to cause a sound joint
- Where a fault exists
- Why a proper brazing or soldering technique is necessary

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS: Machine Design
Metallurgy
Metal Fabrication Methods

USE IN INDUSTRY:

Laboratory Analysis of Production Techniques
Laboratory Analysis to Certify a Joining Technique

MATERIALS AND EQUIPMENT:

Prepared specimens of "Joints," brazed, welded, soldered, sintered.

Microscope to examine specimens, desirable to have 35mm camera attachment for making photographic record of specimens.

35mm slide projector

All preparations may be accomplished by the individual if metallurgy laboratory equipment is available. Examinations of pictures from American Welding Society handbooks or the Welding Journal magazine may also fulfill the needs of the class.

EDUCATIONAL MEDIA:

35mm - instructor prepared - see slide series D-1 through 14.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Observe safety rules of using welding equipment when preparing specimens. Some etchants require care in handling because of toxicity.

PRESENTATION:

Slide No.	Description
D - 1	You are viewing part of the joint area of a soldered lap joint: Tin plated sheet steel joined with 50/50 solder. Observe that solder fills the gap between the pieces and also forms a fillet at the edge. Magnified 50X.
D - 2	Same as D-1 except magnified 100X. Solder in the joint is about 0.0015 thick. The grain structure of the sheet steel is now visible.
D - 3	This is another soldered joint, 5 0/50 solder and galvanized sheet metal. Notice that the tin/lead of the solder has alloyed with the zinc coating on the steel. You see this as a darker line at each interface. Magnification 50X.
D - 4	Same as joint D-3 except magnified 100X. The solder filler metal can be more easily seen as it filled surface irregularities of the base metal. Interalloying of zinc-tin-lead is more pronounced. The spot in the lower left area of the slide is surface corrosion that occured between polishing the specimen and photographing it.

D - 5	A soldered lap joint: Copper sheet metal joined with 50/50 solder. Note absence of visible interalloying bond between solder and base metal. Surface alloying has occured even though not observable at 50X.
D - 6	Same as D-5 except magnification is 100X. Crystal structure of tin/lead solder is visible at 100X.
D - 7	This specimen is the cross section of an arc welded joint; mild steel base metal and electrode (E 6-13). The fusion line is visible at 50X. The metal on either side of this line was molten when joint was made. The "measles" on the slide are localized corrosion occuring at the grain boundaries.
D - 8	Same as D-7 except magnified 100X.
D - 9	A brazed welded joint area magnified 50X. Cast iron joined with a copper based filler metal. Clear interface definition shows that the cast iron did not melt. It also shows intimate contact of two materials. Greater magnification than I was able to get would show filler metal penetration of grain boundaries and voids in the cast iron causing some of the bonding to actually be mechanical.
D - 10	Same as D-9 except 100X magnification. The large dark spot on left hand side of slide is a graphite inclusion. Some interface alloying is visible here.
D - 11	A brazed welded joint at 50X magnification. Mild steel joined with a copper based filler metal. Examination of joint area shows burr produced in joint preparation. Notice that filler metal has completely encapsulated the burr as well as surface alloyed the base metal.
D - 12	Same as D-11 except 100X magnification.
D - 13	Specimen is iron powder compressed and sintered. Sintering at 1600° F. for 30 minutes produced a dense mass with high compressive strength and a Rockwell B-43 hardness. Iron powder particles

became surrounded by a matrix of "plastic" metal at 1600° F. to lock the particles into a rigid mass.

D - 14 Same as D-13 except 100X magnification.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Prepare specimens
Identify bonding mechanism upon examination of slide
Explain defects if observable and devise corrective technique
Check strengths of the various types of joints.

UNIT EVALUATION:

The student will demonstrate by destructive testing that proper techniques and materials are necessary for a satisfactory result. The student should be able to convey his understanding of the subject both verbally and orally to others.

DEFINITION OF TERMS:

1. Interface: The contact area of base metal and joining metal.
2. Weld: Joining with or without a filler metal resulting in a diffusion of materials one into the other; promoted by heat, pressure, chemical action, vibratory energy, or any combination thereof.
3. Braze Weld: Joining with a non-ferrous filler metal above the melting point of the filler metal, but below the melting point of the base metal in a range of 1000° F. or higher.
4. Soldering: Same general definition as brazing, but below 1000° F.
5. Sintered: To heat a mass of fine particles (metal) for a prolonged period of time below the melting point of the particles to cause bonding of adjacent surfaces.

REFERENCES:

1. American Welding Society Handbook - 5th ed.
2. Metals Handbook Vol. 1 - 8th ed., American Society for Metals.
3. ASTM Standards, Part 31, American Society for Testing and Materials.

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: W. J. Champagne
Southeastern Louisiana College
Hammond, Louisiana 70401

INSTRUCTIONAL LEVEL: College

TITLE: Non-ferrous Metals Modifications

PRESENTATION TIME: 5 hours

INTRODUCTION:

Developing alloys is a most effective method of taking advantage of special desired properties of non-ferrous metals. However, in many cases just alloying is not sufficient. Modifications can also be accomplished by plastic movements, cold or hot, heat treating and other methods.

The different modifications number into the hundreds and utilize a wide variety of base metals. This paper will not list every known non-ferrous modification. Nevertheless, it will present a fairly detailed overview of some of the popular modifications used today.

OBJECTIVES:

Develop learning situations so that students will gain basic knowledge of non-ferrous metal modifications, their purposes, properties and uses so that he will be able to design and perform purposeful experimentation and provide effective communication.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:
Science - Atomic level of alloying atoms, work hardening reactions-metal grain changes, etc.
English - Report writing of experiment results, technical reports, etc.

USE IN INDUSTRY:
1. Cold working for added strength-forging.
2. Annealing for relieving stressed conditions.
3. Hardening for added strength or mechanical properties.

4. Hot working for greater density.
5. Stress relieving for partial recovery.

MATERIALS AND EQUIPMENT:
1. Adequate supply of non-ferrous alloys
2. Microscope
3. Specimen preparation equipment
    Polishers, abrasives, etchants
4. Furnace, Oven
5. Hardness tester
6. Universal tester for strengths
7. Quenching tanks and several quenching solutions
8. Projection equipment
    Overhead, movie, slide
9. Torches, hand held

EDUCATIONAL MEDIA:
Student and teacher demonstrations
Transparencies and/or slides:
    lattice structures, charts of uses, diagrams of grains, equilibrium diagrams, interstitial atoms, substitutional atoms
Movies:
    grain structure, deformation movements, coatings, galvanic actions (electroplating)
Equilibrium diagrams charts

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:
1. Furnace handling rules and operations
2. Personal clothing, gloves, aprons, gloves, etc. for handling acids, furnaces, etc.
3. Handling hot metals; tongs, asbestos plates, gloves, etc.

PRESENTATION:

I. Identification and purposes of non-ferrous metals.
    A. Definitions
        1. Base metal
        2. Alloy
        3. Working metal-hot and cold
        4. Coating non-ferrous metals
        5. Cladding
        6. Solutions
            a. Liquid
            b. Solid

- 7. Phases and phase diagrams
- 8. Age hardening
- B. Advantages
  - 1. Corrosion resistance
  - 2. High weight-strength ratio
  - 3. Electrical conductivity
  - 4. Thermal conductivity
  - 5. Low melting point
- C. Disadvantages
  - 1. Economics
  - 2. Low in strength when compared to ferrous alloys

II. Modifications

- A. Alloying
  - 1. Methods
    - a. Melted separately and then mixed
    - b. Adding lower melting solids to an already melted higher melting point metal
    - c. Additions in the ladle prior to pouring.
    - d. Additions in the mold
  - 2. Solubility in each other
  - 3. Solutions
    - a. Solid
    - b. Liquid
  - 4. Equilibrium diagrams
  - 5. Phases
  - 6. Equilibrium conditions
  - 7. Non-equilibrium conditions
- B. Heat-treating
  - 1. Recovery
  - 2. Annealing
  - 3. Precipitation or age hardening
    - a. Heating
    - b. Cooling
    - c. Aging
      - (1) Artificial
      - (2) Natural
    - d. Suppressing precipitation
- C. Working below the recrystallization point-cold working
  - 1. Grain deformations
    - a. Slip and slip planes
    - b. Twinning
    - c. Metal flow and directional properties
  - 2. Advantages of wrought metals
  - 3. Relationship between stress and strain in plastic flow
  - 4. Rolled grain flow
  - 5. Forged grain flow
  - 6. Disadvantages - dangers in overwork

D. Working above the recrystallization point-hot working
  1. Grain deformation
  2. Recrystallization
  3. Grain quality advantages
  4. Disadvantages during heated conditions
  5. Rolled grain flow
  6. Forged grain flow

E. Coatings
  1. Natural oxidation protection
  2. Metallic
    a. Powder applications-sheardizing
    b. Applied while molten-hot dip
      (1) Zinc
      (2) Tin
      (3) Cadmium
      (4) Lead
    c. Electroplating
      (1) Nickel
      (2) Chromium
      (3) Tin
      (4) Zinc
      (5) Cadmium
      (6) Precious metals
  3. Organic
    a. Tar derivatives
    b. Lacquers
    c. Enamels
    d. Paints
    e. Synthetic rubbers
  4. Cladding

III. Testing - Student set-ups from above treatments
  A. Strengths
    1. Tensile
    2. Compression
    3. Hardness
    4. Impact
    5. Modulus of elasticity
    6. Transverse loading
    7. Shear
    8. Fatigue
    9. Creep
  B. Coating exposures-corrosive environments
  C. Coating thicknesses-bending-measurements-adherances
  D. Conduction
    1. Electrical
    2. Thermal

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:
- Demonstrations
- Technical reports
- Oral reports
- Performance evaluations

UNIT EVALUATION:
- Regular unit test or tests
- Oral tests, reports
- Performance evaluations, manipulative
- Assigned experiments

DEFINITION OF TERMS:

1. Additive - An element or elements mixed with a base material
2. Age hardening - Hardening with time by precipitation of particles from within lattice structures to grain boundary locations.
3. Alloy - A base metal containing one or more additional metal or non-metal for better strength, ductility, etc.
4. Annealing - Heating and slow cooling to produce soft conditions.
5. Base metal - The metal being altered, either by alloying, working, coating, or a combination of methods.
6. Cold working - Working (plastic deformation) metal below its recrystallization point.
7. Equilibrium conditions - Suitable time allotment for all precipitants to come out of solution, or for completion of all normal reactions.
8. Heat-treating - Applying heat to alter properties of metal, hardening or softening.
9. Hot working - Working (plastic deformation) metal above its recrystallization point.
10. Modifications - A base metal alteration designed to create special properties needed for corrosive protection or added strength.
11. Non-ferrous - Not derived from iron.
12. Phase - Cycle of change - a heterogeneous system consisting of two or more homogeneous systems - any heterogeneous section of a heterogeneous system.
13. Precipitate - To become insoluble and separate out of solution.
14. Precipitation - Being released or precipitated from a solution.

15. Solution - Dispersing one or more elements in another, solid or liquid.
16. Solution treatment - Heat treatment to trap elements in solution.

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7. Hurd, Paul S., Metallic Materials: An Introduction to Metallurgy, Holt, Rinehart and Winston, Inc., New York, 1967.
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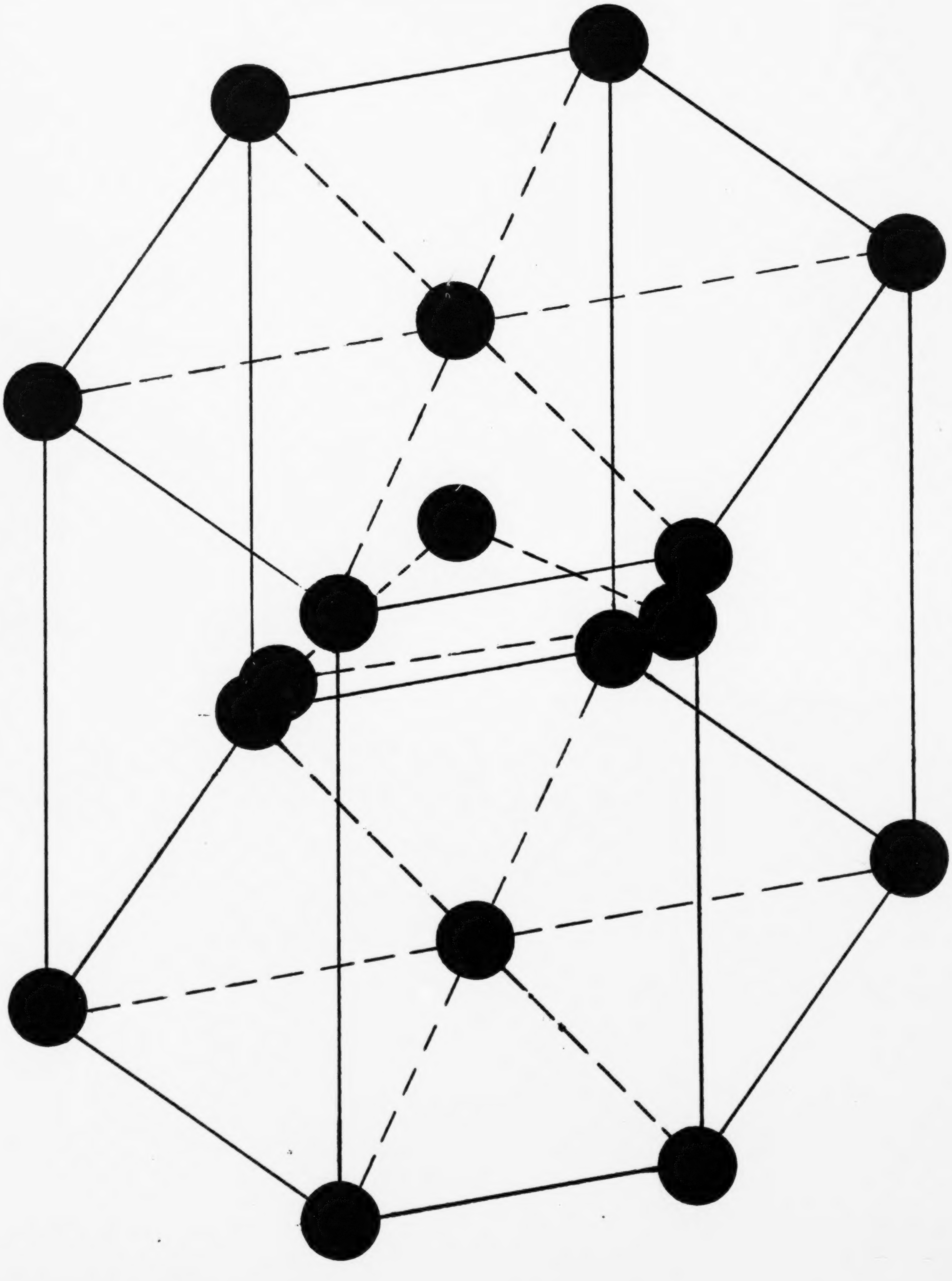
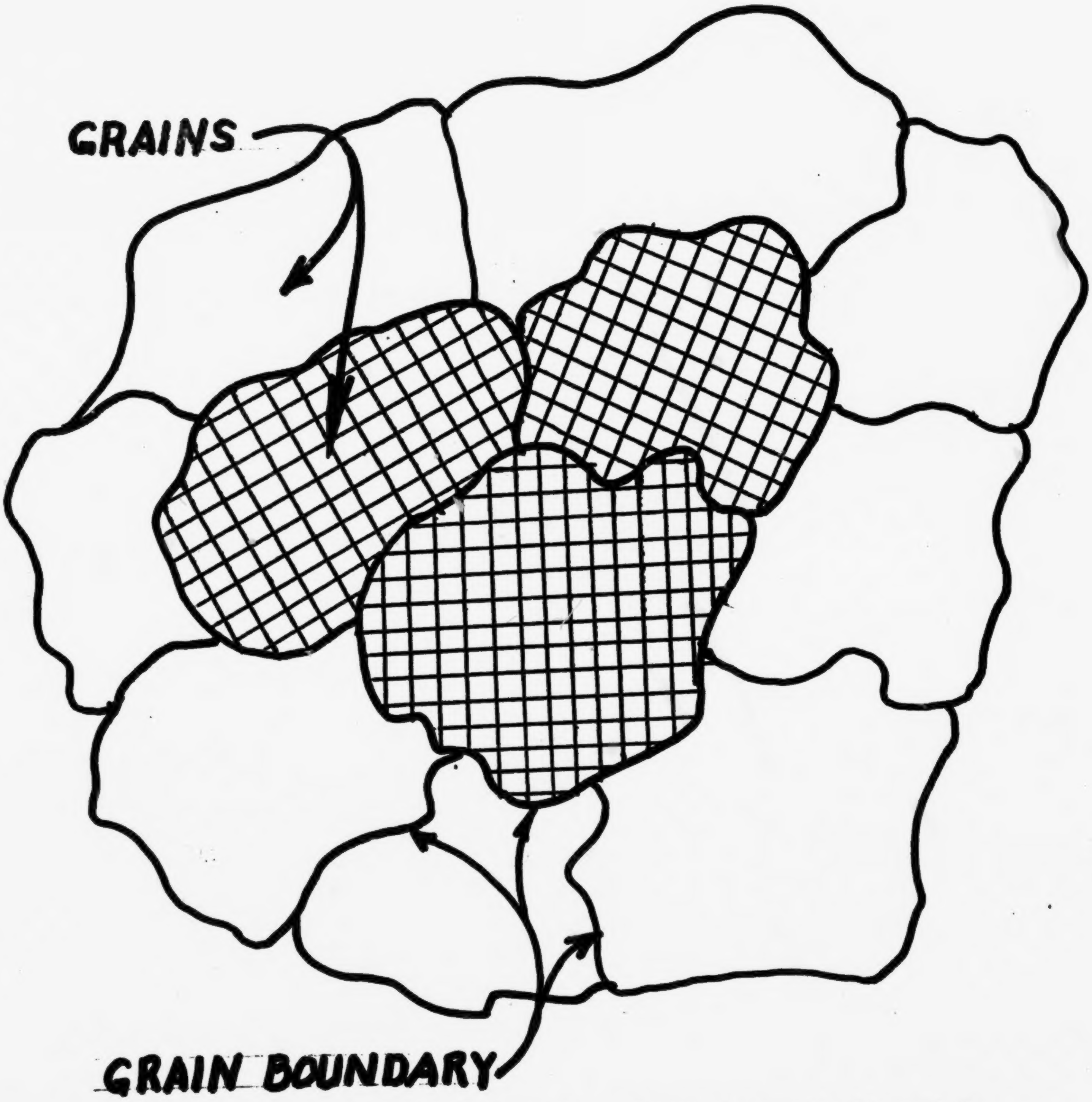
9. Moffatt, William G., George W. Pearsall, and John Wulff, The Structure and Properties of Materials, John Wiley and Sons, Inc., New York, 1966.
10. Moore, Harry D., and Donald R. Kibbey, Manufacturing Materials and Processes, Richard D. Irwin, Inc., Homewood, Illinois, 1965.
11. Rogers, Bruce A., The Nature of Metals, American Society for Metals, Cleveland, Ohio and the Iowa State University Press, Ames, Iowa, 1964.
12. Samans, Carl H., Metallic Materials in Engineering, The Macmillan Co., New York, 1963.
13. Scientific America, Inc., Materials, W. H. Freeman and Co., San Francisco, 1967.
14. Seymour, Raymond B., Hot Organic Coatings, Reinhold Publishing Co., New York, 1959.
15. Van Vlack, Lawrence H., Elements of Materials Science, Second Edition: Addison-Wesley Publishing Co., Inc., Reading, Massachusetts, 1964.

HEXAGONAL CLOSE-PACKED LATTICE

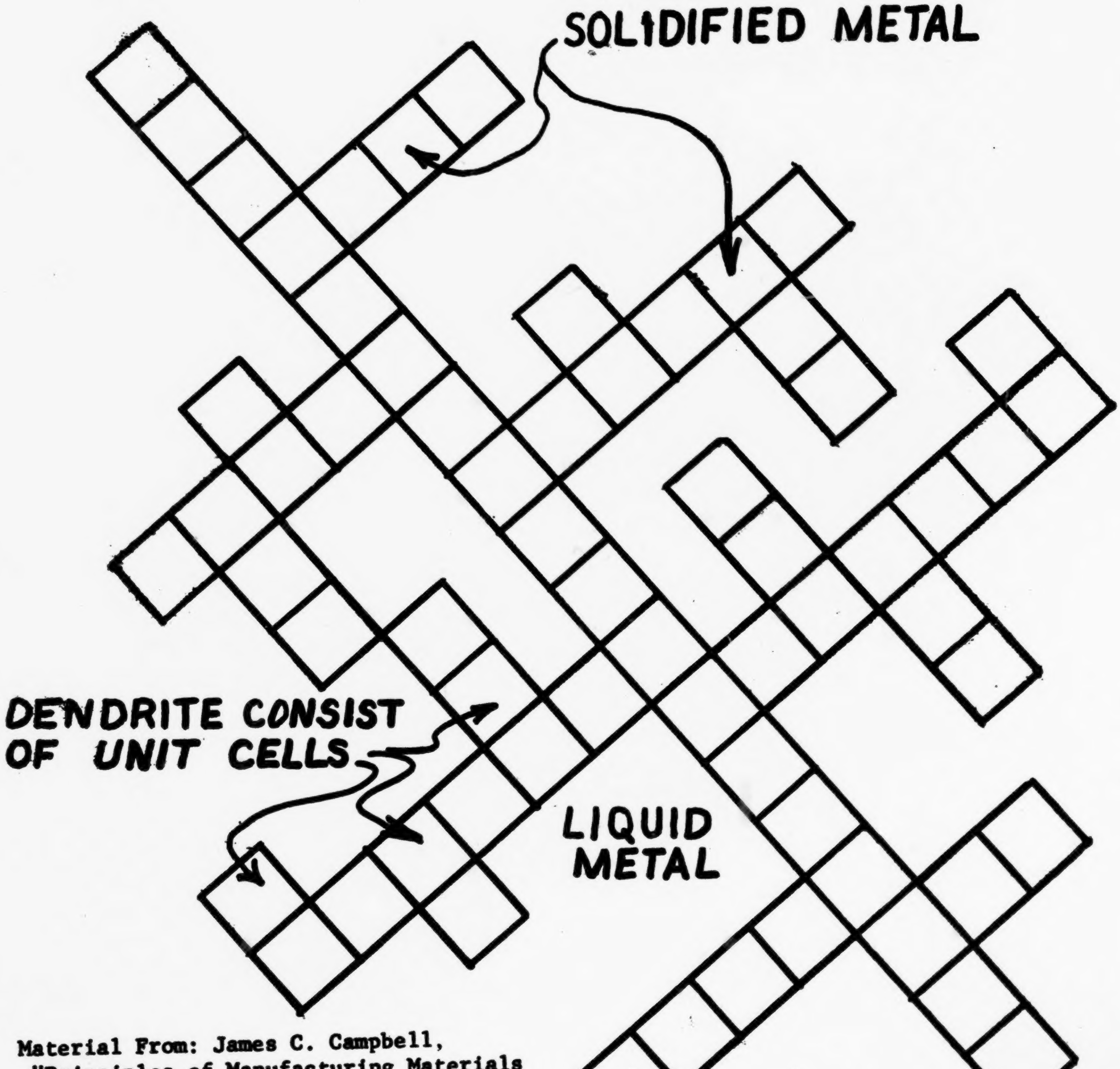


CRYSTALLINE STRUCTURE IN A SINGLE GRAIN


GRAINS
GRAIN BOUNDARY

Material From: James C. Campbell's "Principles of Manufacturing Materials and Processes"

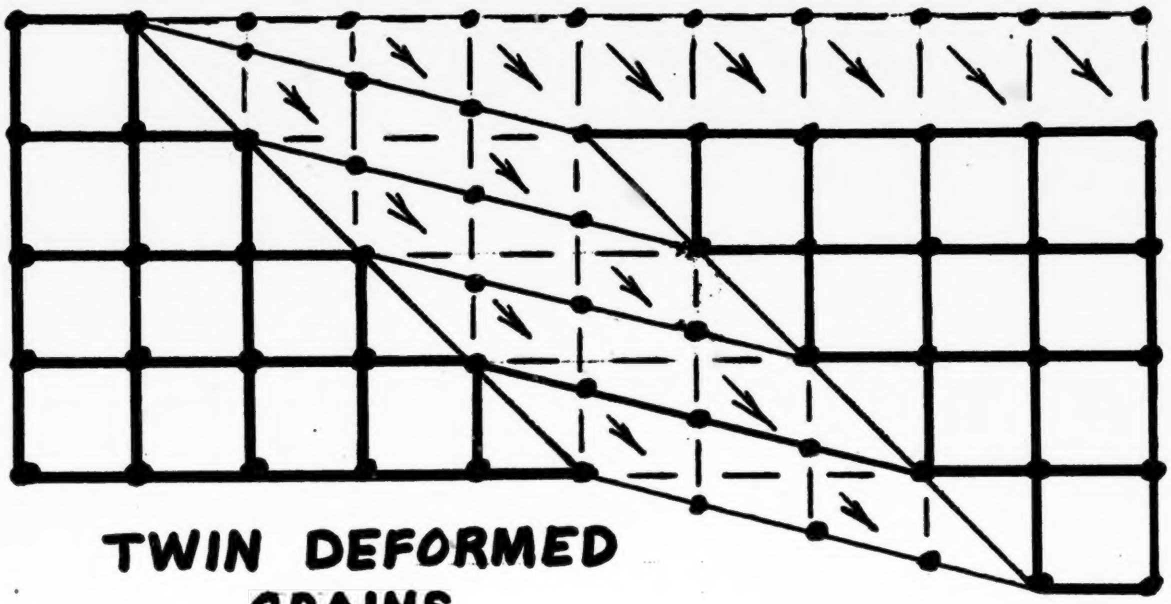
DENDRITIC GROWTH PATTERN


SOLIDIFIED METAL
DENDRITE CONSIST OF UNIT CELLS
LIQUID METAL

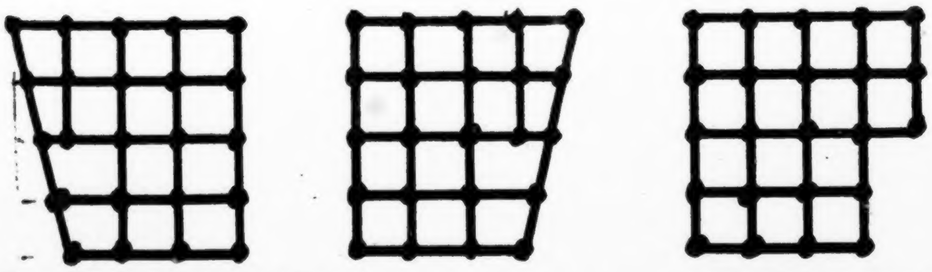
Material From: James C. Campbell, "Principles of Manufacturing Materials and Processes"

THREE DIMENSIONAL GROWTH-TWO SHOWN

PLASTIC DEFORMATION



TWIN DEFORMED GRAINS

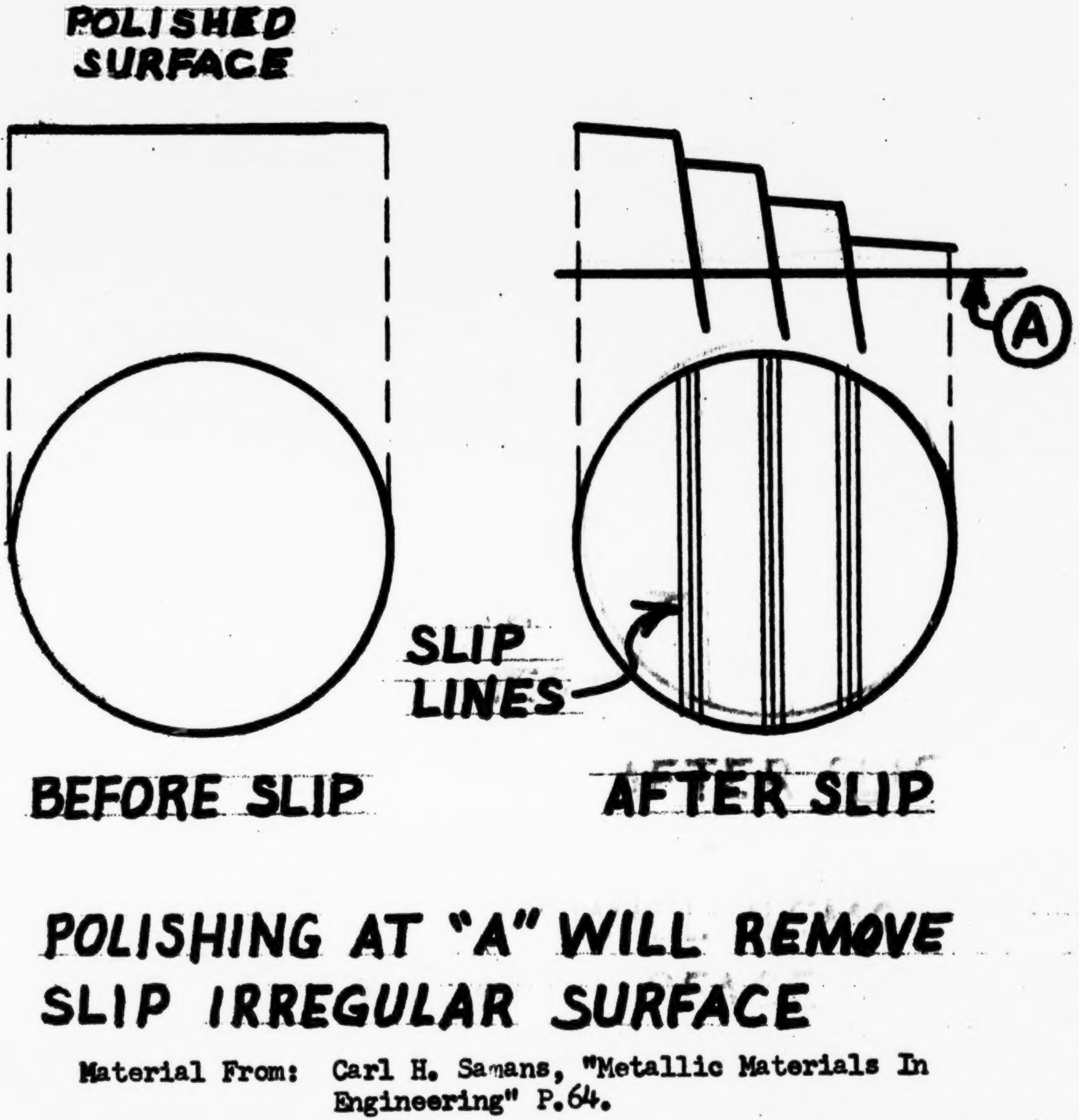


BEFORE SLIP AFTER SLIP

DISLOCATION SLIP

Champoeg I

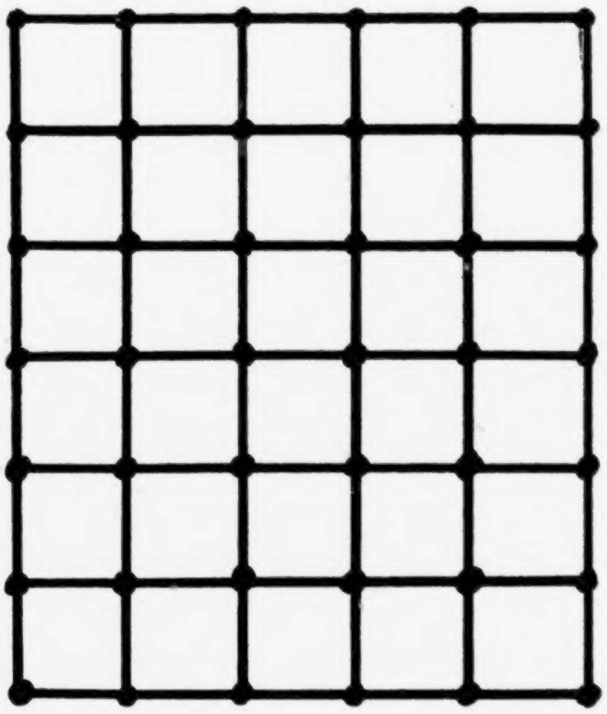
FORMATION OF SLIP LINES


POLISHED SURFACE
A
SLIP LINES
BEFORE SLIP
AFTER SLIP

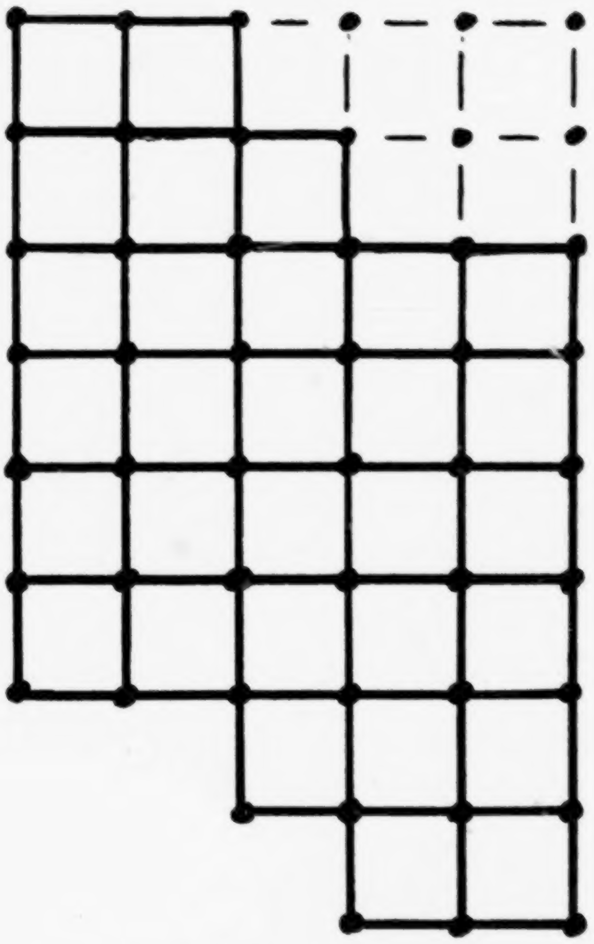
POLISHING AT "A" WILL REMOVE SLIP IRREGULAR SURFACE

Material From: Carl H. Samans, "Metallic Materials In Engineering" P.64.

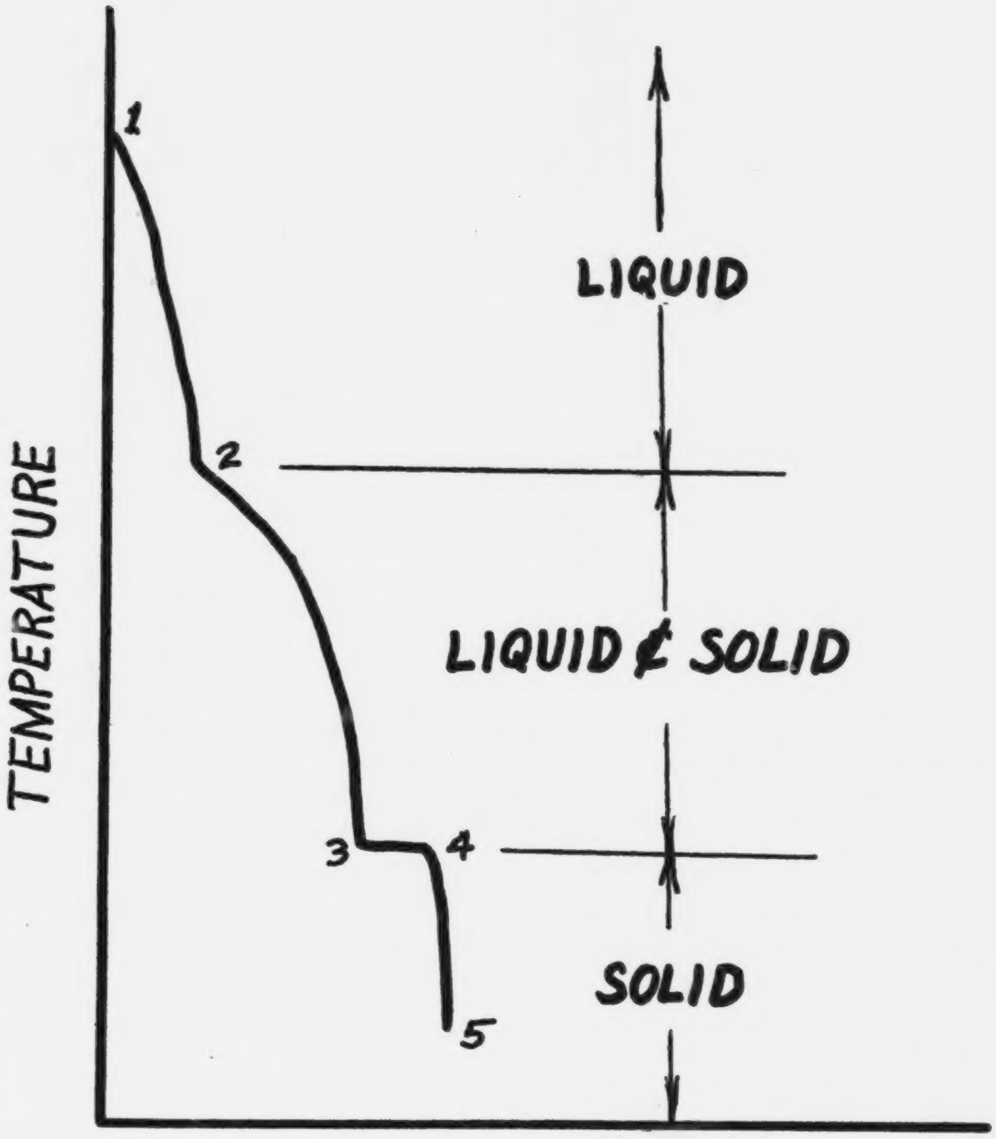
PLASTIC DEFORMATION



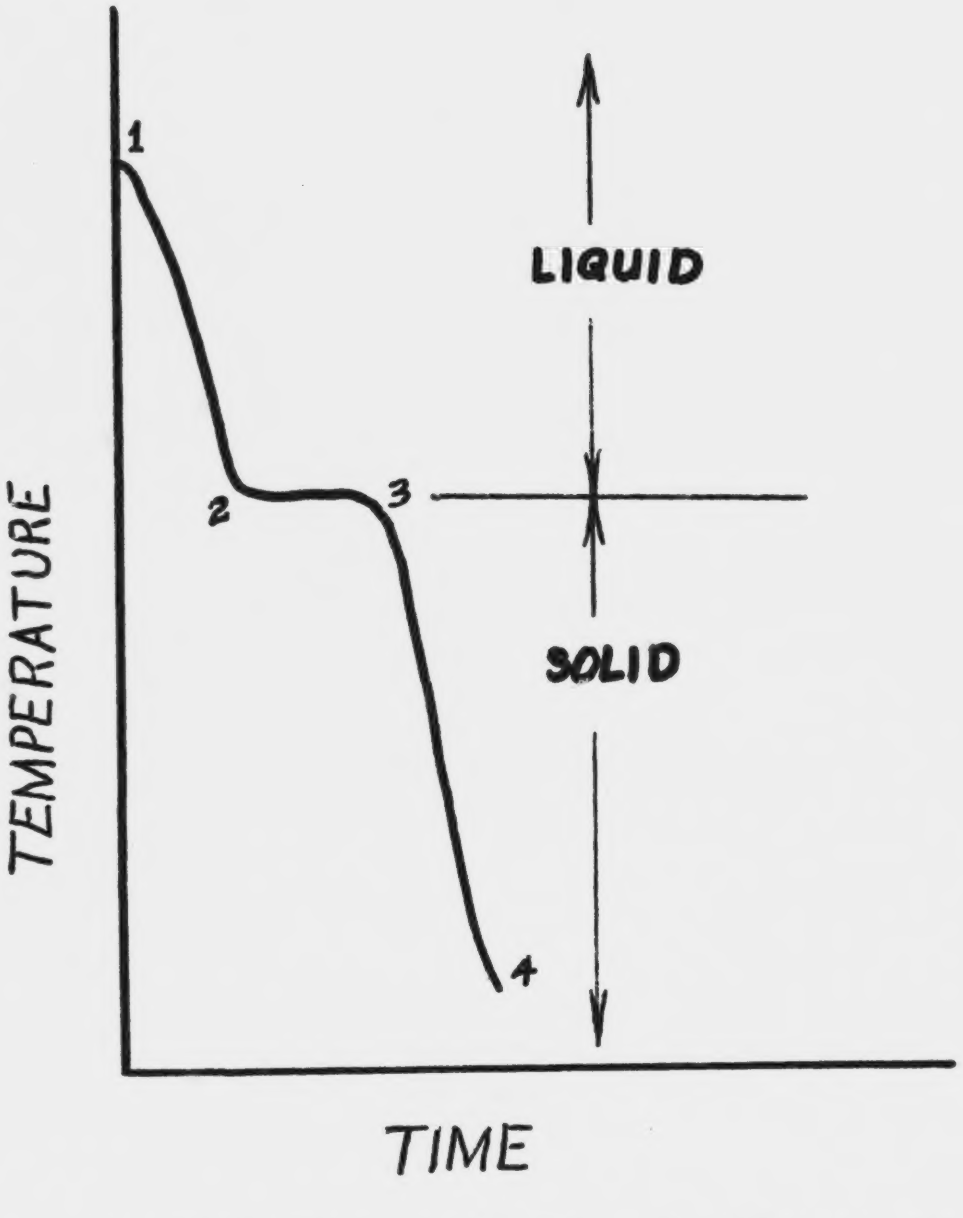
UNSTRAINED GRAINS



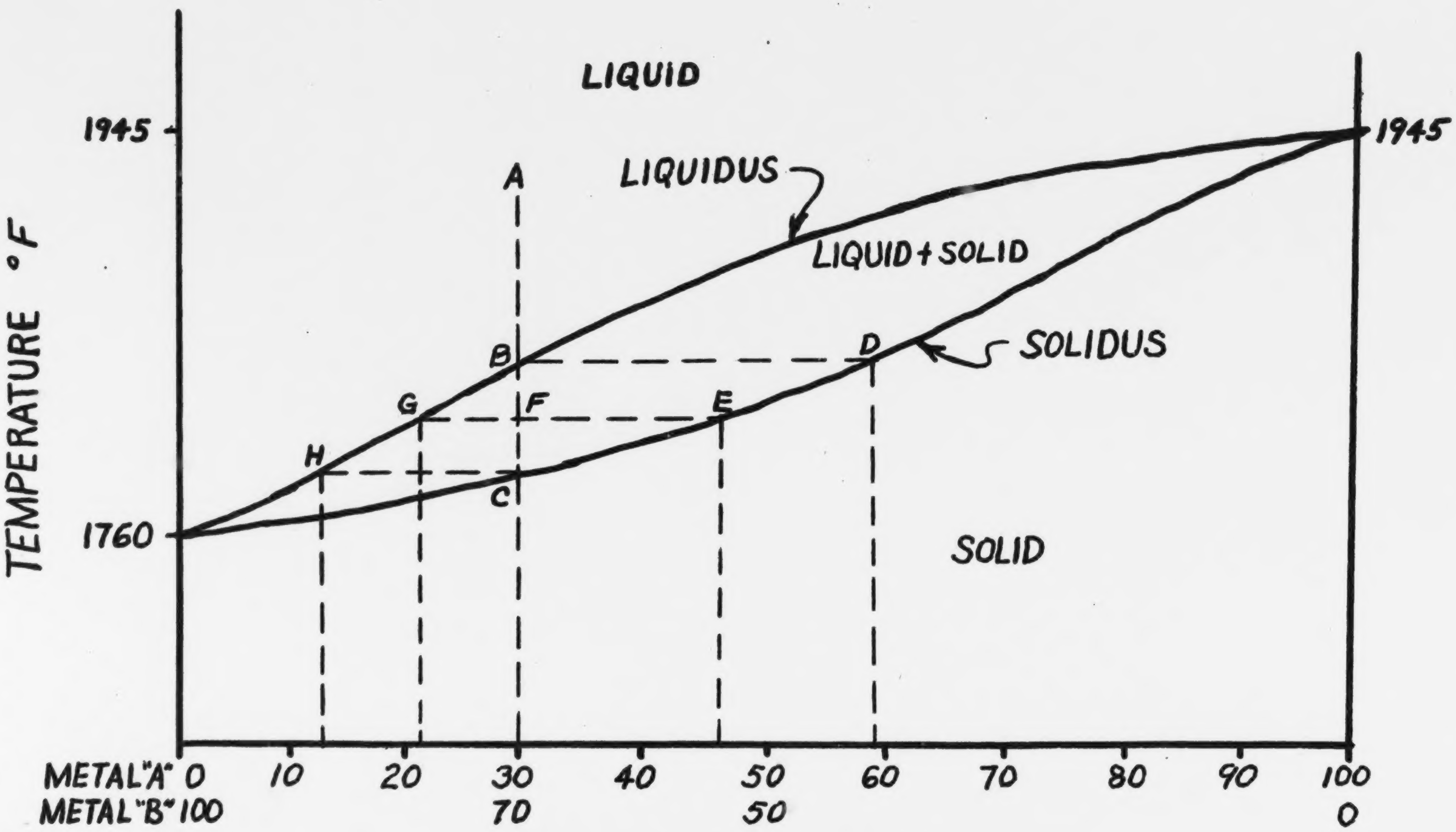
SLIP DEFORMED GRAINS



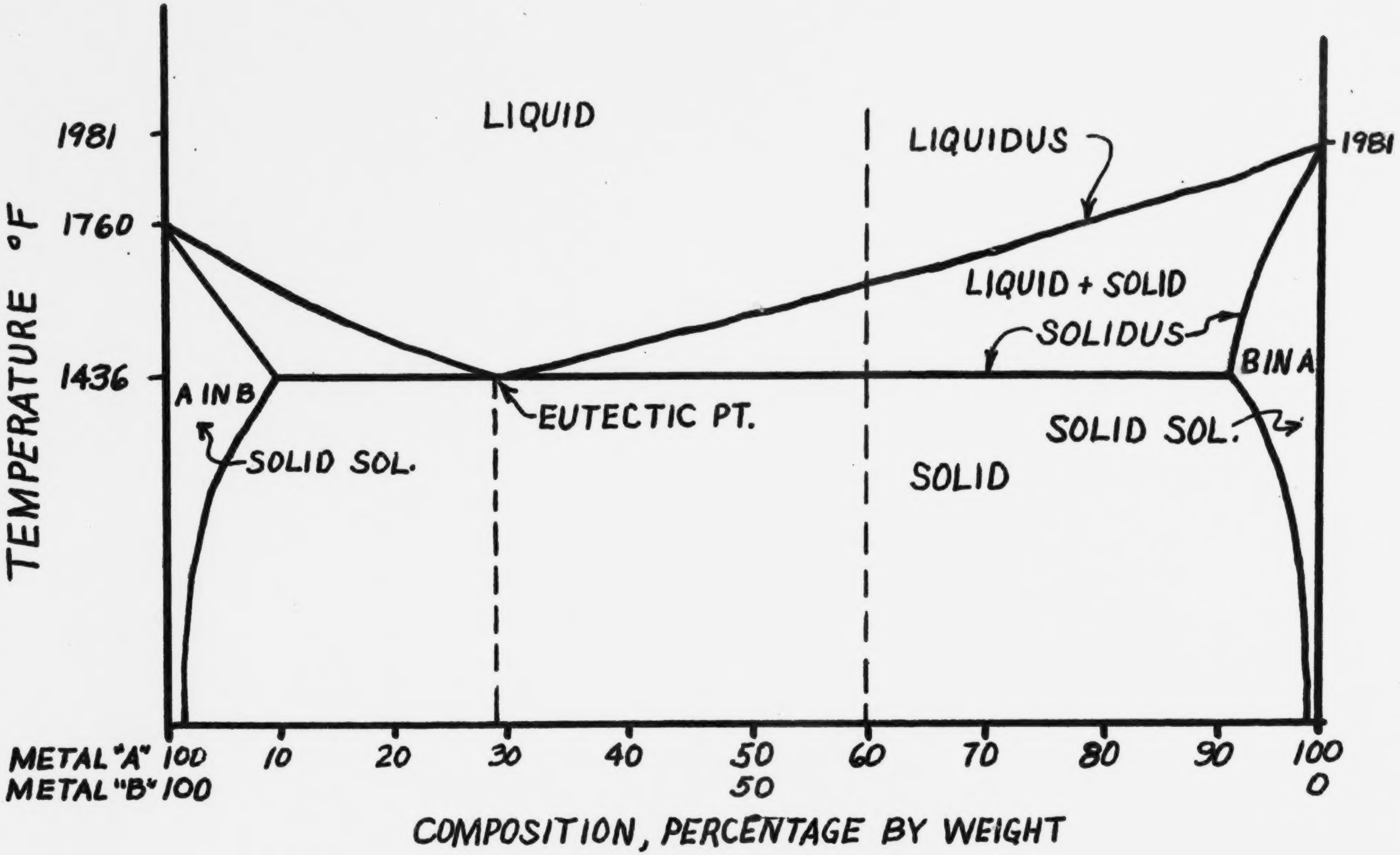
BINARY ALLOY COOLING CURVE



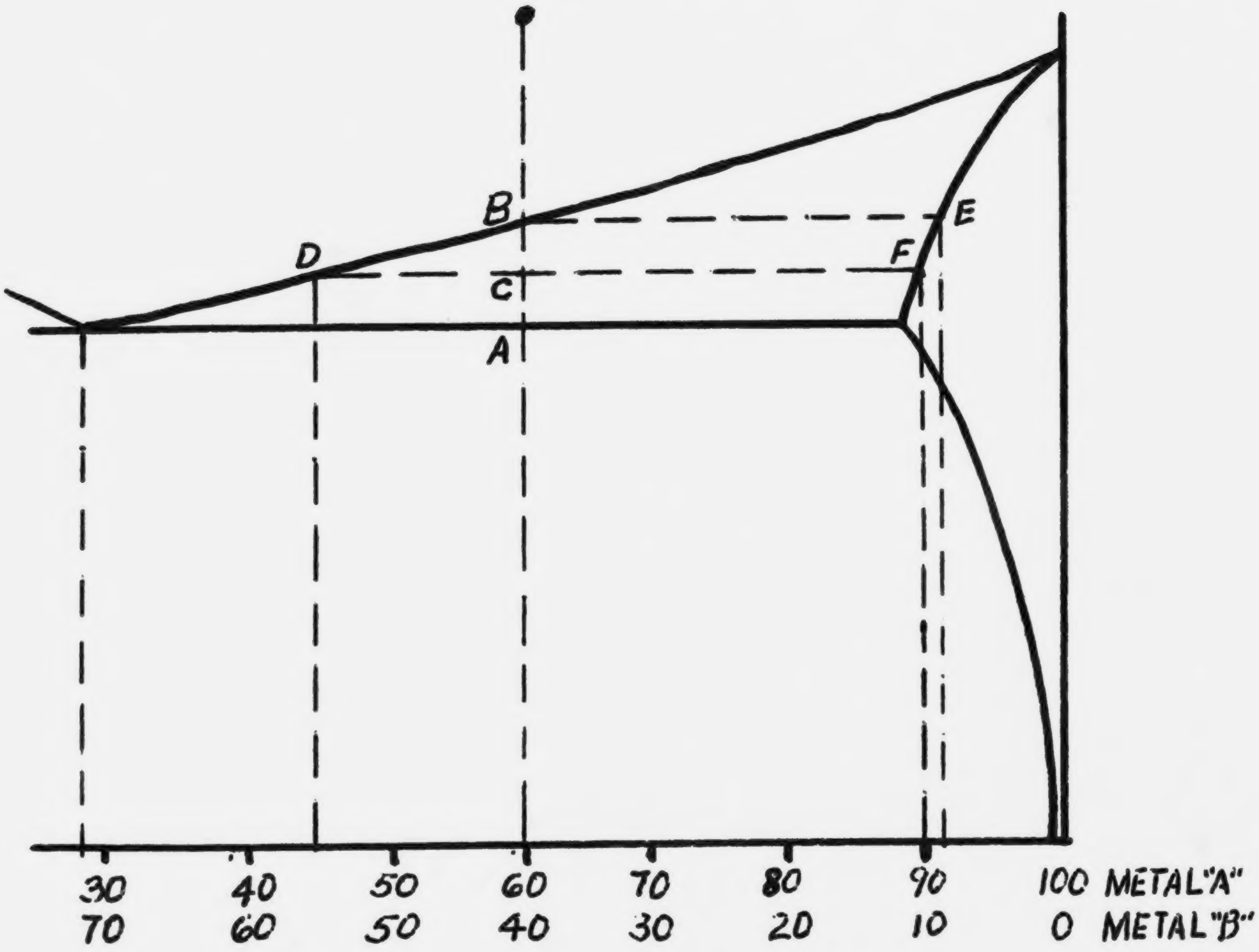
EUTECTIC ALLOY OR PURE METAL
COOLING CURVE



EQUILIBRIUM DIAGRAM

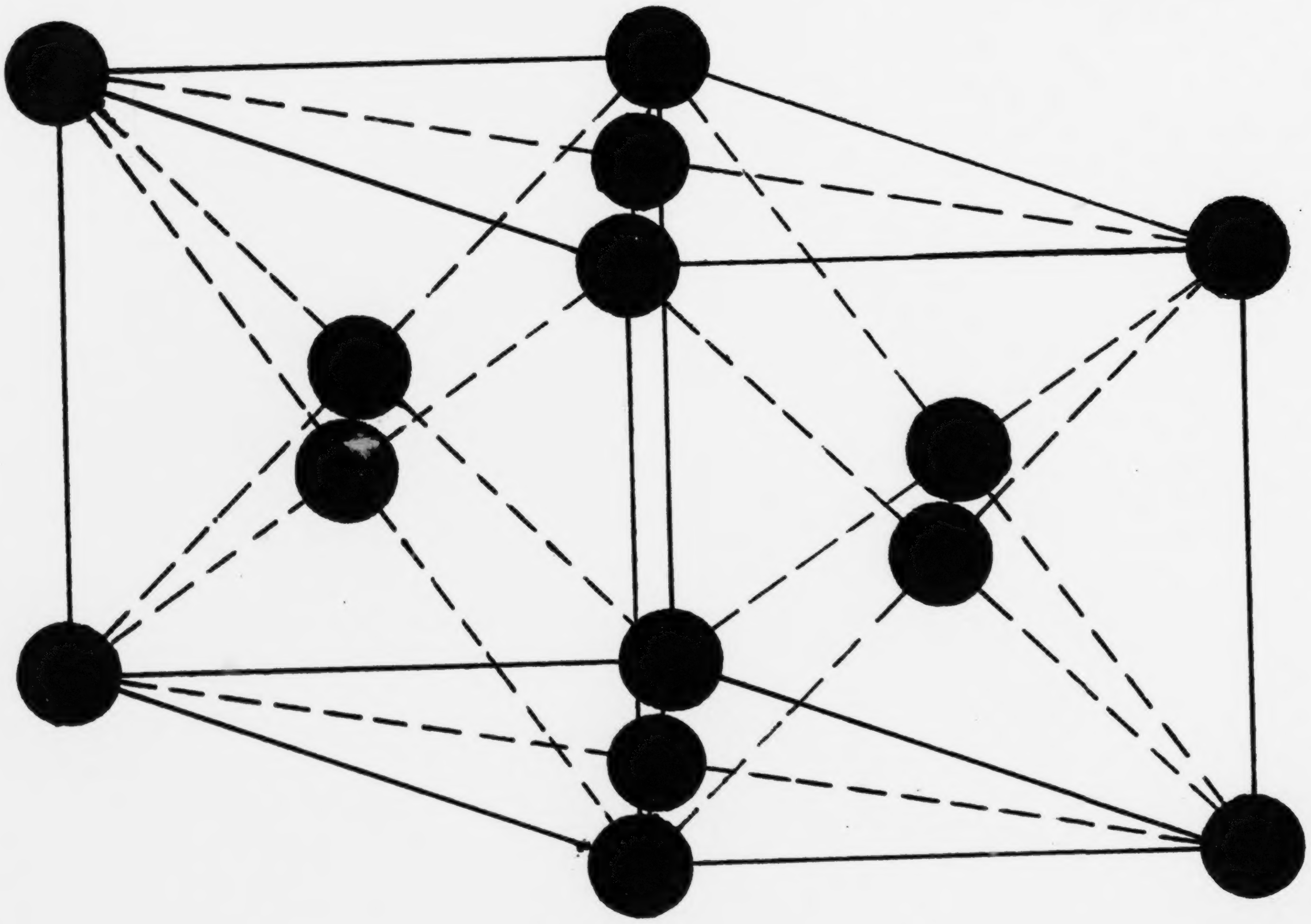

LIQUID
LIQUIDUS
1981
1981
1760
1436
TEMPERATURE °F
LIQUID + SOLID
SOLIDUS
BIN A
A IN B
EUTECTIC PT.
SOLID SOL.
SOLID SOL.
SOLID
METAL "A" 100
METAL "B" 100
10
20
30
40
50
50
60
70
80
90
100
0
COMPOSITION, PERCENTAGE BY WEIGHT

EQUILIBRIUM DIAGRAM

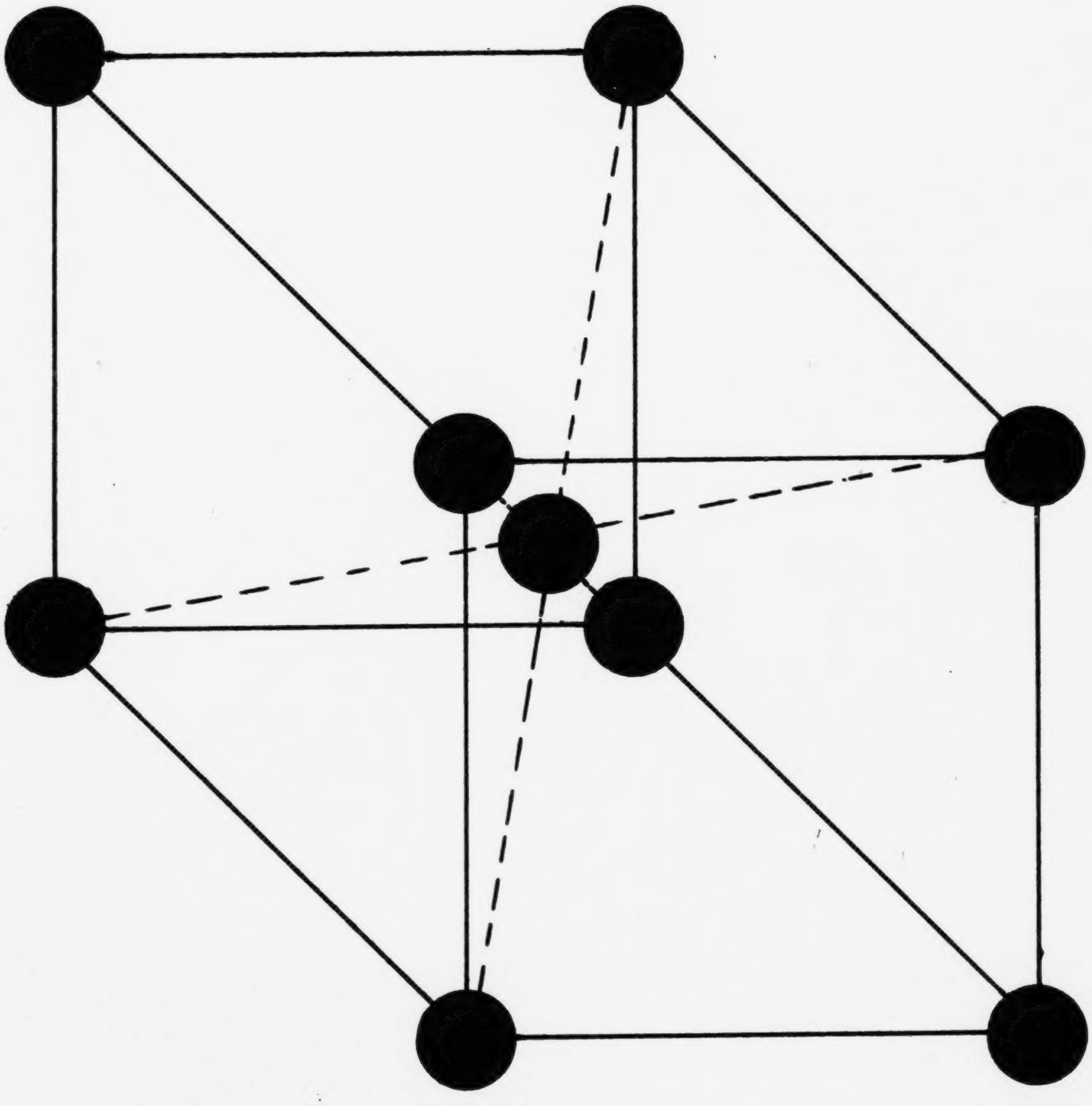

B
D
C
A
E
F
30
70
40
60
50
50
60
40
70
30
80
20
90
10
100 METAL "A"
0 METAL "B"

EQUILIBRIUM DIAGRAM

FACE-CENTERED CUBIC LATTICE



BODY-CENTERED CUBIC LATTICE



SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Willard R. McAtee
Pioneer High School
1290 Blossom Hill Road
San Jose, California

INSTRUCTIONAL LEVEL: Junior High School, Senior High School or College.

TITLE: Steel Corrosion (Zinc Protection)

PRESENTATION TIME: 1 hour

INTRODUCTION:

Since man fails to find most metals in their pure or usable state, he must separate them from compounds (mixtures) as they were naturally deposited in the earths crust during the years of its geological formation. The law of nature states, All matter seeks a state of neutral electrical balance. This law is clarified by the natural process of iron corrosion. As an example, Iron Ore ⟶ Iron+ Corrosion ⟶ Iron Oxide or ore. Man has devised scientific ways of protecting his metals to slow down or stop the corrosion process. We will limit this lesson to a study of steel and the protection against corrosion provided by the metal zinc.

OBJECTIVES: (Behavioral and Terminal)

1. To identify iron.
2. To identify zinc coated iron.
3. To write the sequence of refining (mine to converters).
4. To organize items to accomplish an experiment.
5. To observe and record results of an experiment.
6. To solve better than seven out of ten multiple choice. test questions.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELATION WITH OTHER SUBJECTS:
Science--Galvanic series of metals.
Periodic chart of the elements.
Salt solution.
Oxidation of metals.
Ionization and electron displacement.

USE IN INDUSTRY:

PREVENT CORROSION: (Industry-Construction-Farms-Homes-Transportation (land and marine)

1. Galvanizing - manufactured products.
   a. hot dip
   b. Continuous strip
2. Electro-galvanizing
   a. Wire, conduit, hardware, and fasterners
3. Metallizing (Spraying)
   a. No distortion of welded sections
   b. High alloy steel
   c. Thickness must vary--large objects
4. Sherardizing
   a. Tumble action in zinc dust particles
5. Zinc rich paint.
   a. Fast economical coatings

MATERIALS AND EQUIPMENT:

A. Experiment
   1. Jar, glass
   2. Strip of zinc
   3. Conductor
   4. Nail
   5. Galvanized iron strip
   6. Tin plate strip
   7. Salt water
   8. Pencils
   9. Paper
   10. Magnet

B. Demonstration
   1. Oxyacetylene torch
   2. Mild steel rods
   3. Asbestos
   4. Soldering iron
   5. Solder and flux

EDUCATIONAL MEDIA:

1. Easel
2. Magnetic board
3. Discussion outline
4. 35mm. strip and slide projector
5. Overhead transparency projector and transparencies
6. Space suitable to teach and demonstrate the concepts

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

1. Wear laboratory goggles while working the experiment.
2. Pass items to be handled to classmates carefully.

PRESENTATION:

1. Prepare the instructional environment.
2. Introduce self (magnetic board)
3. Introduce the lesson topic - "Corrosion" (magnetic board)
    a. Ask motivational questions
        - Why do so many cars have defective exhaust systems?
        - Why doesn't stainless silverware rust or tarnish?
        - Why is salt stored in fiber glass or resin tanks?
        - What is meant by galvanic or anodic protection?
4. Assign reading topic, "Corrosion of Steel," A Scramble Book for Self Instruction
5. Prepare the instructional environment.
    a. Finish details of instructional environment.
        1. 35 mm. slide projector.
        2. Overhead transparency projector.
        3. Demonstration and experiment preparation.
6. Summarize the reading assignment. (page 1, item 3 of Scramble Book, "Corrosion of Steel".
7. Teach the story of how man separates iron (Fe) from iron ore.
    a. Mining
    b. Blast Furnace
    c. Converters

    Let students manipulate realia samples.
    Demonstrate identification of iron by magnetic properties.
8. Teach the story of Corrosion
    a. Corrosion is the deterioration and loss of material due to chemical attack. The conditions that promote corrosion involve both chemical and electronic change.
    b. The most common type of corrosion involves the electrochemical process of metal oxidation. Oxidation is the removal of electrons from an atom. Rust is ferric hydroxide, and is formed according to the overall reaction of:

    $$4\ Fe + 3\ O_2 + 6\ H_2O \longrightarrow 4\ Fe\ (OH)_3$$

    c. For rust to occur both oxygen and moisture must be provided or present.
    d. Different metals have different oxidation potential, inasmuch as the energy required to remove electrons varies from metal to metal. As example, electrons are removed from iron when moisture and oxygen are present and from aluminum when chloride ions are present.

e. Galvanic cells produce corrosion. They can be categorized in three different groups: (1) composition cells, (2) stress cells, and(3) concentration cells. Any contact of two dissimilar metals is a potential source of galvanic corrosion.
Composition cells. (Any contact of two dissimilar metals.) Example - Zinc and iron. Iron is the cathode and zinc becomes the anode.
Stress cells. Heat treatment may effect the corrosion rate by altering the microstructure of the metal. A fine grained metal will have a higher corrosion rate than a course grained metal, because there is more anode area. The grain boundary area may be considered to be stressed since the atoms are not at their positions of lowest energy. In metal that has been cold worked, strain (stress) will result in the strained area becoming the anode and the strain free area will be the cathode.
Concentration cells. The concentration cell accentuates corrosion, but only where the concentration of the electrolyte is lower. The most important type of concentration cells are the oxidation-type concentration cells. When oxygen and moisture come in contact with metal, corrosion occurs. However, the most corrosion will occur where the oxygen was deficient. The reaction that occurs in an oxygen free area and results in corrosion is stated

$$2\,H_2O + O_2 + 4e^{-} \qquad 4\,(OH)^{-}$$

The oxygen removes electrons from the metal, thus the areas adjacent must supply the additional electrons, thereby becoming anodic.

Summary. Most corrosion is a result of the setting up of galvanic cells and the accompanying electrical currents. Two dissimilar electrodes are required: (1) differences in composition, (2) differences in energy level (stressed areas), (3) differences in electrolytical environment. The electrode with the higher potential is the anode. The anode undergoes corrosion while the cathode is protected.

9. Teach the story of how man protects his metal (Iron)
   a. Only under ideal conditions can corrosion be prevented. However, we can minimize the effects from it and it is well worth the effort.

b. There are three primary methods of preventing corrosion.
   1. The isolation of electrolytes from electrodes.
      a) Protective surfaces.
   2. The avoidance of galvanic couples.
      a) Limit designs to one metal or use 18-8 stainless steel. The chromium develops a passive skin (austenite).
   3. Use galvanic protection.
      a) Reference to trans. #1
      b) Plating or anode connected electrically.
         1) Barrier protection (tinplate)
         2) Sacrificial protection (zinc)

10. Student Performance
    a. Demonstrate the experiment procedure after brief introduction
       1. Issue Experiment Guide Sheet, Steel Corrosion-Zinc Protection.
       2. Divide the class into small groups of two per group and allow the students to perform the experiment. Emphasize safety. Wear eye protection.
       3. Be sure to follow up by recording results over the next few days.
11. Oral Summary and Discussion. Items 7, 8, and 9 of the presentation outline.

Lesson Evaluation Space: Notes to remember.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE

1. Student will manipulate realia associated with the lesson.
2. Student will set up and evaluate experiment as directed in small groups.
3. Students will take the evaluation test.
   - Attempt to solve ten multiple choice test questions.
   - Write three major processes of steel production.
   - Sketch the set-up of the experiment using pictorial projection.

UNIT EVALUATION:

1. Oral summary and discussion with students.
2. Student written test results.
3. Resident teacher comments.
4. Observation teachers from the Institute.

DEFINITION OF TERMS:

1. Corrosion - Slow destruction of metals by chemical attack.
2. Conductor - Copper stranded wire with insulation.
3. Galvanize - To coat with zinc.
4. Compound - Molecular mixture of various elements.
5. Stress - Points of distortion.

REFERENCES:

STUDENT:

1. Booklet - Zinc Controls Corrosion, American Zinc Institute.
2. Scramble Book, Corrosion of Steel, Teacher authored.

TEACHER:

1. Preparing Instructional Objectives, Robert F. Mager.
2. Elements of Materials Science, Lawrence H. Van Vlack.
3. The Zinc Industry - A Mine To Market Outline., The American Zinc Institute, Inc.
4. Encyclopedia Britannica, Vol. 6., 1968, pp. 546-549.

CORROSION OF STEEL

A

SCRAMBLE BOOK

FOR

SELF-INSTRUCTION

INSTRUCTION

This is a programmed text. Learning from programmed instruction is probably different from anything you have ever done. To learn the most from this program, follow the directions given below.

1. Each page is numbered at the top. On each page you will find a series of numbered paragraphs. As you proceed thorugh this scramble book, you will be guided by the paragraph and page numbers.
2. At the end of each paragraph there is a direction telling you to what new paragraph and page you should turn.
3. When you have turned to the new paragraph and page you will have a choice of two answers. After selecting the answer you believe to be correct, turn to the page your selected answer indicates.
4. Upon turning to the new page, you will find out if your answer is correct.
5. If your answer is incorrect, you will be given further instructions as to what to re-study.
6. If your answer is correct, you will have new information to read.
7. You continue progressing through the book until you have read the entire book and answered all the questions.
8. Turn to page 1, paragraph 1 and begin reading.

1. INTRODUCTION: Since man fails to find most metals in their pure or usable state he must separate them from compounds as they were deposited in the earths crust during the years of its formation.

   The law of nature, "All matter seeks a state of neutral balance," is clarified by the example of iron going through the natural process of corrosion. (Simplified) Iron Ore → Refined Ore and Water → Iron Ore.
   Man has devised scientific ways of protecting his metals to slow down or stop the corrosion process. We will limit this lesson to the study of steel and the protection against corrosion provided by the metal zinc.

   Turn to page 2, Item 1.

---

2. Your selection is incorrect, return to page 3, Item 1

---

3. No matter where iron is used the most economical and efficient way of protecting the metal against corrosion is to utilize zinc protection, as outlined on page 3, Item 2.

   In summary - The law of nature states all matter tries to achieve a state of neutral electrical balance. Man refines iron from ore, preserves it through zinc protection and nature tries to get it back to its original state through corrosion.

THE END

1. All matter seeks a state of neutral electrical balance.
    1. If you believe this to be True turn to page 3, Item 1.
    2. If you believe this to be False turn to page 4, Item 1.

---

2. It is the elements of oxygen and water that combines with iron to cause corrosion. Iron will rust when both moisture and oxygen are present in the environment.
    1. If you believe this statement to be False, turn to page 1, Item 2.
    2. If you believe this statement to be True turn to page 4, Item 2.

---

3. Your selection was incorrect, turn to page 4, Item 2.

No. 3

1. You are correct. All matter seeks a state of neutral electrical balance.

   Iron in its refined and usable form is usually in an unstable state. It has a valence of +2 in the outer N shell of its atom. It is the elements of oxygen and water that combine with iron to cause corrosion. Corrosion is defined as the slow destruction of metal by chemical attack.

   Turn to page 2, Item 2.

---

2. Zinc protection of iron is provided by both barrier and galvanic action. Galvanizing is accomplished by either hot dip or continuous strip.

   Metallizing is spraying melted zinc.

   Sherardizing is tumbling items in zinc dust.

   Coating is painting with zinc rich paint.

   Galvanic protection is the best and most reliable against rust of iron.

1. If you believe this statement to be True, turn to page 1, Item 3.
2. If you believe this statement to be False turn to page 2, Item 3.

1. Your answer is incorrect, Turn to page 1, Item 1 and restudy.

---

2. You are correct. Rusting or corrosion is an expensive problem and a waste of our resources. Man has discovered that by using a metal called zinc he can prevent rust by any one of four basic processes, which are:
   Galvanizing, Metallizing, Sherardizing, and
   Zinc Rich Paints, (coatings)

Turn to Page 3, Item 2

JUNIOR HIGH SCHOOL
GENERAL METALS

NAME____________________

DATE____________________

Sample with Answers

TEST

Subject: Steel Corrosion (Zinc Protection)
Instructions: Read the statement, choose the best answer and mark the appropriate slot on the answer sheet.

1. People identify galvanized (zinc coated) steel by which of the following criteria or description.
   a. mirror finish
   *b. feels cold, has a gray flaky crystalline appearance
   c. non-magnetic
   d. rusts easily in water or salt water.

2. A person can slow or prevent corrosion by the following:
   a. tinplating
   b. galvanized iron
   c. alloying chromium and nickel into stainless
   *d. all of the above

3. Iron is separated from the ore while in the:
   a. bessemer
   b. open hearth
   c. oxygen lance
   *d. blast furnace

4. Steel is made by changing the carbon content of iron while the metal is being:
   a. cooled
   *b. remelted
   c. stored in ladels
   d. cast in ingots

5. Galvanized iron is really steel plated with:
   a. lead
   b. solder
   *c. zinc
   d. tin

6. Besides barrier or sheath protection, zinc gives steel an added protection by:
   - *a. electrochemical or sacrificial process
   - b. static process
   - c. becoming an alloy
   - d. sealing cracks and scratches

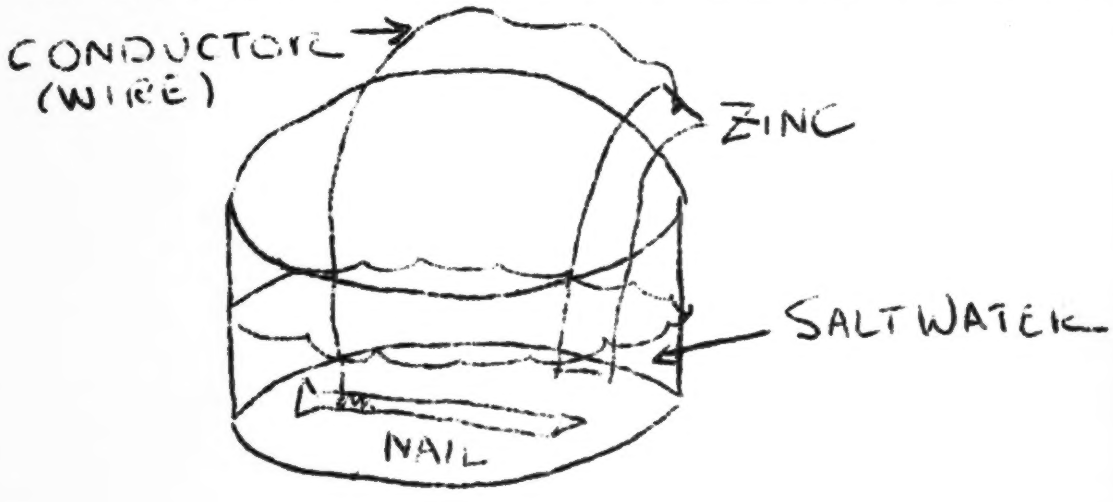
7. Galvanizing sheet stock is done in a:
   - a. cyclotron
   - *b. continuous line mill
   - c. oxygen lance furnace
   - d. soaking pit

8. Metallizing is the process of applying a zinc coat by:
   - a. dipping
   - b. using a centrifugal force
   - *c. spraying molten zinc
   - d. tumbling in zinc dust

9. Sherardizing is the process of applying a zinc protective coat on steel products by:
   - a. hot dipping
   - b. using a centrifugal force
   - c. spraying molten zinc
   - *d. tumbling in zinc dust

10. Outline the three major steps used in steel manufacturing:
    - a. Mining
    - b. Blast Furnace
    - c. Remelting-Converters

11. Make a sketch of the experiment showing the zinc anode, the nail cathode, the conductor and the container of salt water.



TABLES OF METALS IN GALVANIC SERIES

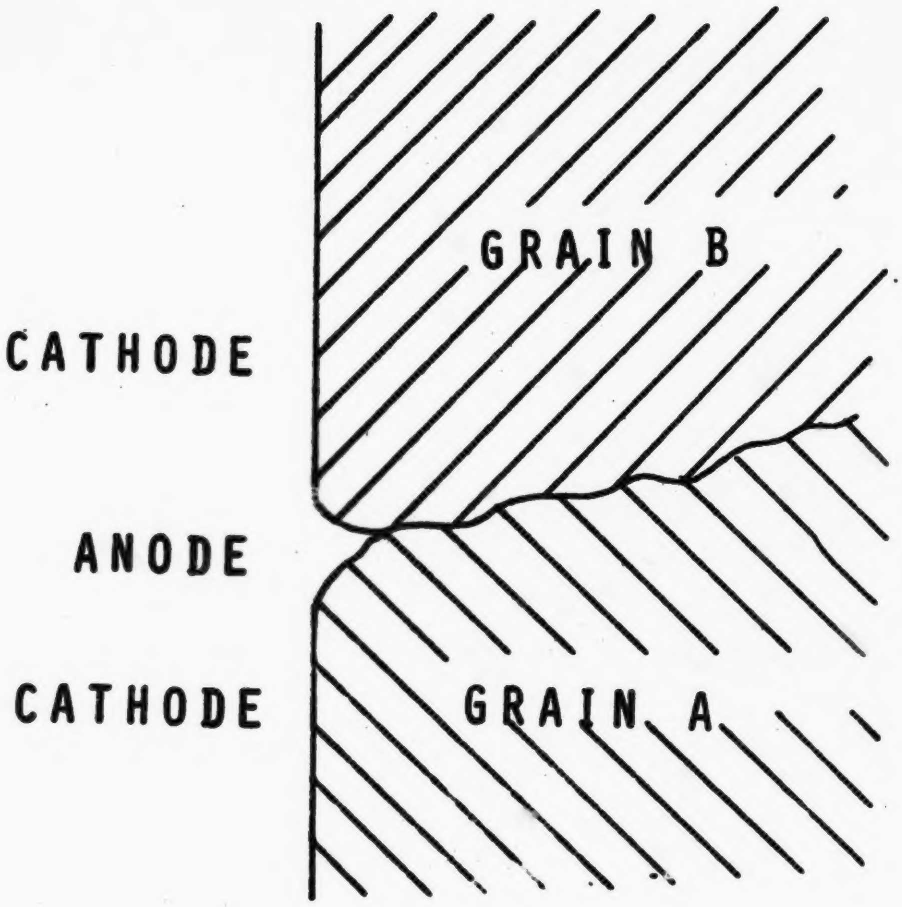
CORRODED END
(ANODIC OR LESS NOBLE)

MAGNESIUM
ZINC
CADMIUM
IRON OR STEEL
STAINLESS STEELS
(ACTIVE)
SOFT SOLDERS
TIN
LEAD
NICKEL
BRASS
BRONZES
NICKEL-COPPER ALLOYS
COPPER
STAINLESS STEELS
(PASSIVE)
SILVER SOLDER
SILVER
GOLD
PLATINUM

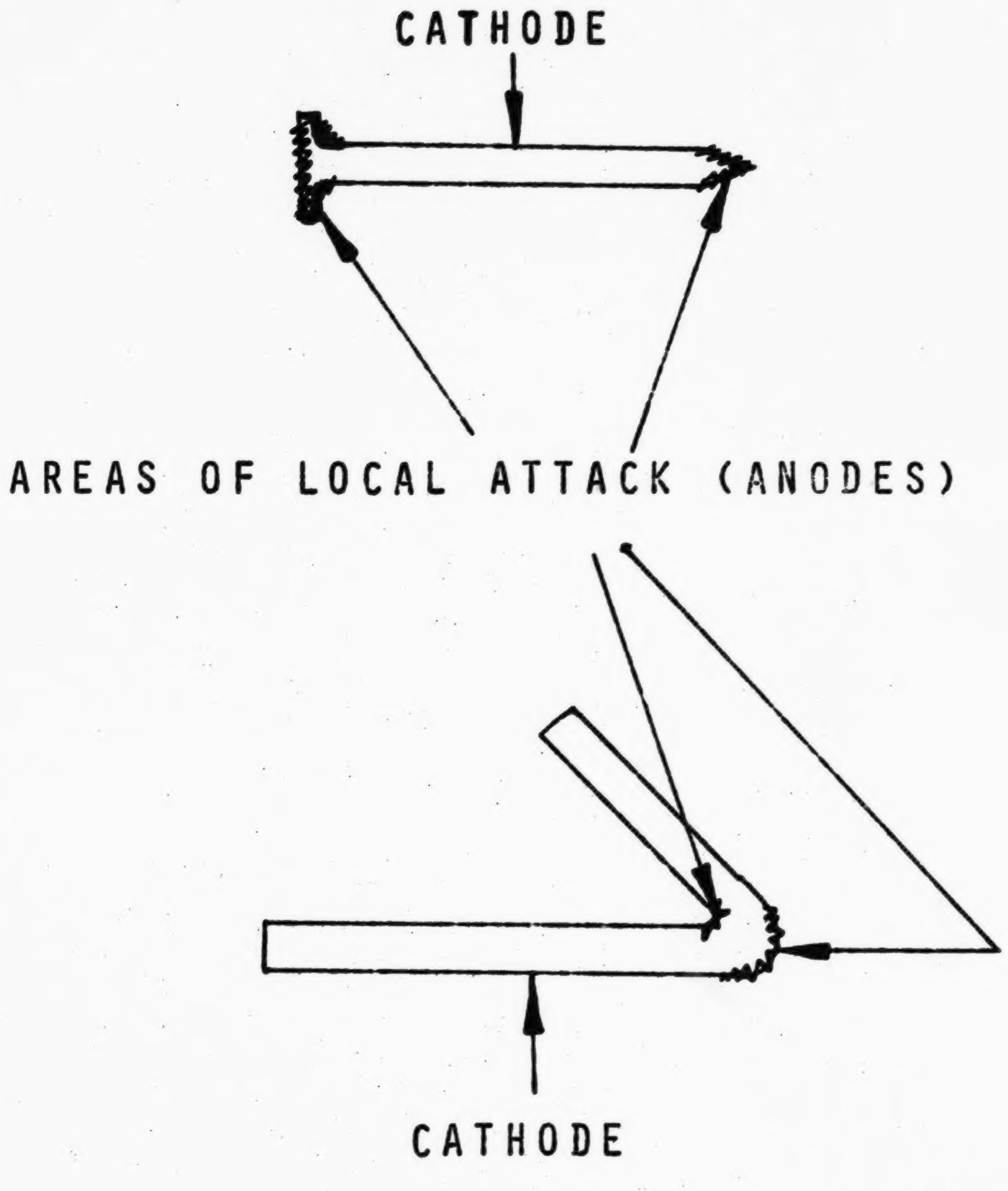
PROTECTED END
(CATHODIC OR MOST NOBLE)

ANY ONE OF THESE METALS WILL OFFER PROTECTION TO ANY OTHER WHICH IS LOWER IN THE SERIES.

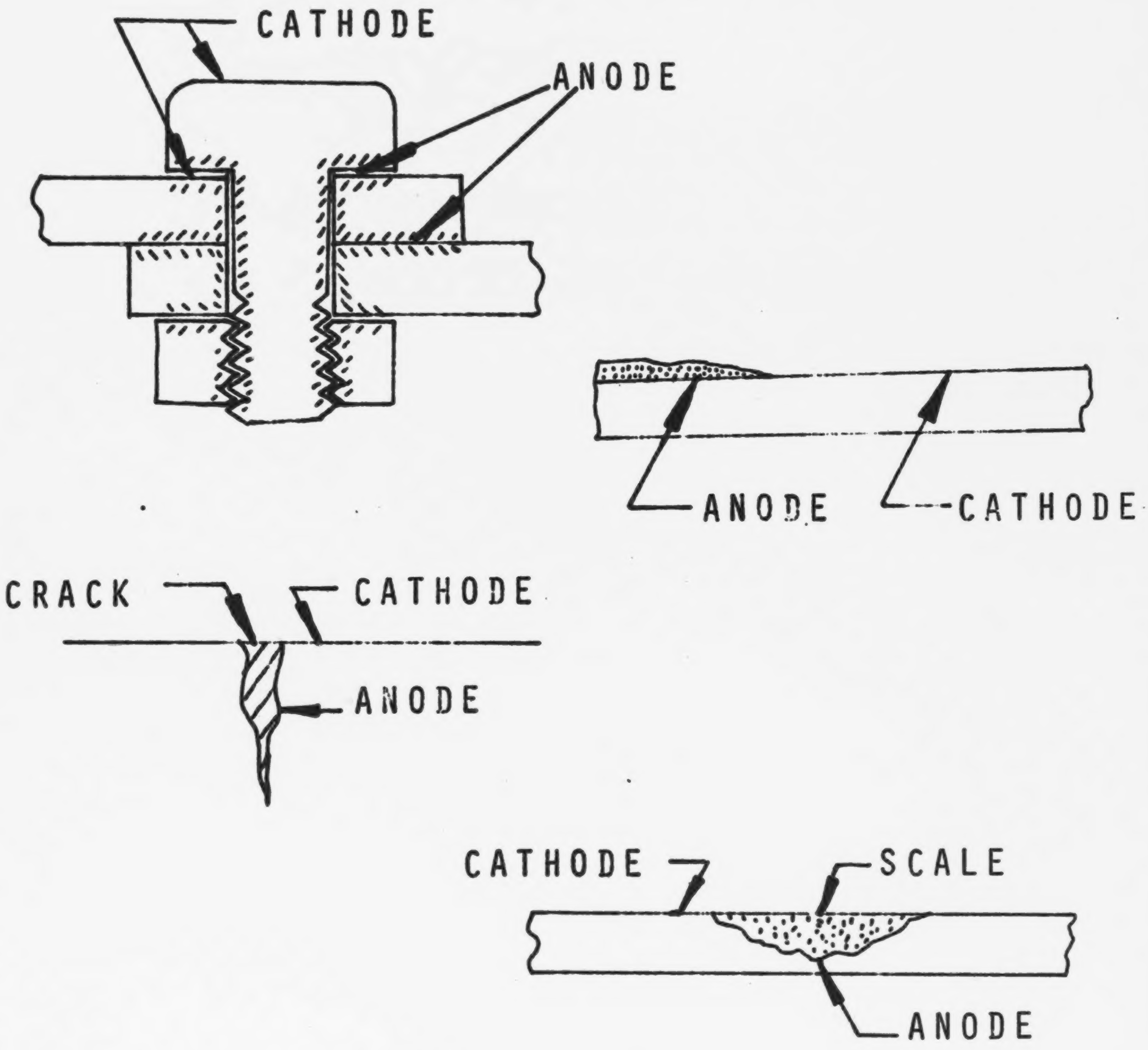
ZINC IS THE MOST EFFECTIVE


GRAIN B
CATHODE
ANODE
CATHODE
GRAIN A

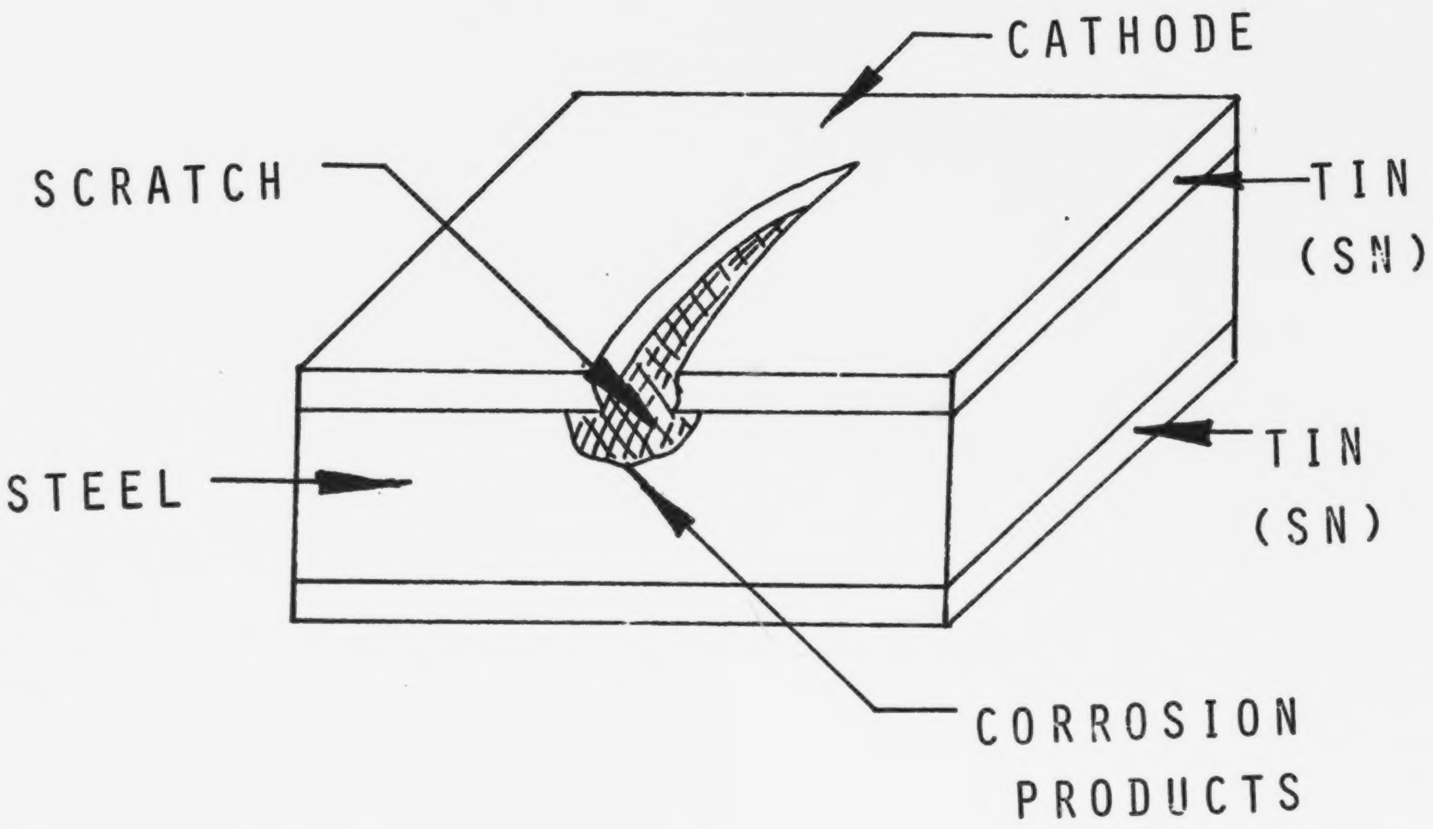
GRAIN BOUNDARY CORROSION


CATHODE
AREAS OF LOCAL ATTACK (ANODES)
CATHODE

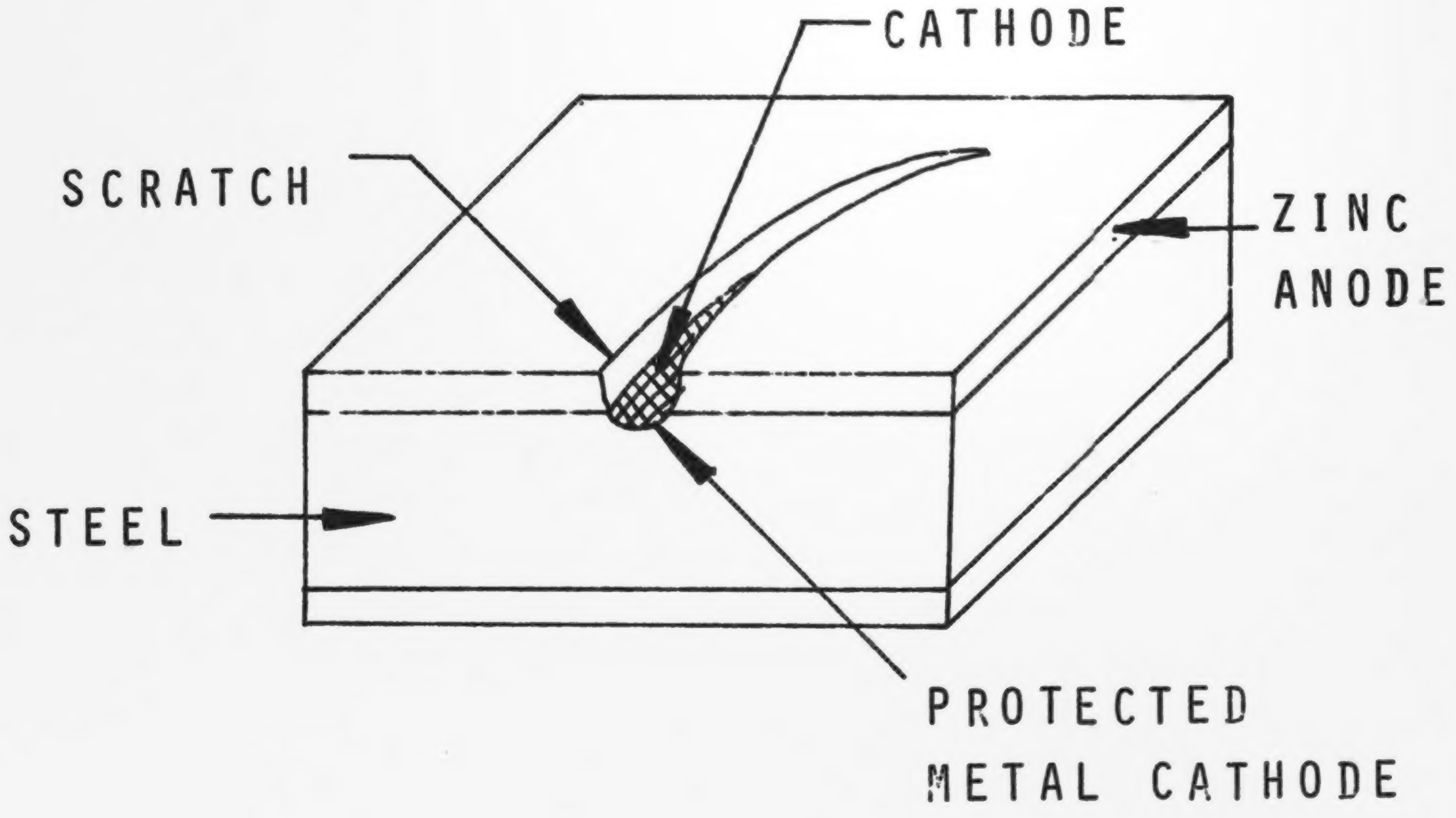
STRESS CELLS


CATHODE
ANODE
ANODE
CATHODE
CRACK
CATHODE
ANODE
CATHODE
SCALE
ANODE

CONCENTRATION CELLS


CATHODE
SCRATCH
TIN (SN)
STEEL
TIN (SN)
CORROSION PRODUCTS

TIN PLATE (STEEL)


CATHODE
SCRATCH
ZINC ANODE
STEEL
PROTECTED METAL CATHODE

GALVANIC PROTECTION,
CORROSION
ZINC PLATED, IRON OR STEEL.

SUMMARY OF GALVANIC CELLS

SPECIFIC EXAMPLES	ANODE	CATHODE
	BASER PHASE	NOBLER PHASE
ZN VS. FE FE VS. H_2 H_2 VS. CU PEARLITE	ZN FE H_2	FE H_2 CU CARBIDE
	HIGH ENERGY	LOWER ENERGY
BOUNDARIES GRAIN SIZE STRESSES STRESS CORROSION	BOUNDARIES FINE GRAIN COLD-WORKED STRESSED AREAS	GRAIN COURSE GRAIN ANNEALED NONSTRESSED AREAS
	LOWER CONC.	HIGHER CONC.
ELECTROLYTE OXIDATION DIRT OR SCALE	DILUTE SOLUTION LOW O_2 COVERED AREAS	CONCENTRATED SOLUTION HIGH O_2 CLEAN AREAS

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDEIS DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Don Whaley
Georgia Southern College
Statesboro, Georgia

INSTRUCTIONAL LEVEL: College

TITLE: Structure of Metals

PRESENTATION TIME: 6 hours

INTRODUCTION:

All materials at the molecular level are held together by certain interacting forces. The forces which exist between atoms of metal are quite different from those of other materials. Consequently, metals have special characteristics which are unique. Industry makes use of these characteristics in many ways. Therefore, it is important that we know as much as possible about the structure of metals in order to be better users of these important materials. How metals can be worked has been our main concern in the past. Now we want to consider why they behave the way they do when we work them, or place them in certain environments. The logical place to begin their study is at the atomic level.

OBJECTIVES:

1. To provide students with knowledge of the structure of metals so that they will have a good foundation for additional study of these materials.
2. To aid students in understanding the relationship between atomic and molecular structure, and the properties of metal.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metals

INTER-RELTION WITH OTHER SUBJECTS:

This unit closely related with other units in industrial arts because of the similarity of matter. It should support chemistry, physics and math, especially geometry.

USE IN INDUSTRY:

Industry makes wide use of knowledge of the structure of metal. Metals industries are constantly looking for better metals to provide customers, such as NASA, with their material needs. Knowledge of the structure of metals is a must when metallurgists attempt to alloy for certain sophisticated properties.

MATERIALS AND EQUIPMENT:

1. Overhead projector
2. Various lab equipment such as beakers, bunsen burners, etc.
3. Chalk board
4. Periodic chart of the Elements
5. Molecular model kits
6. Models of crystal lattices made from assorted styrofoam balls of different sizes and colors.
7. Samples of metals
8. Metallography microscope
9. Metal samples for micro examination

EDUCATIONAL MEDIA:

The instructor should expect to use a number of aids in presenting this unit. It is rather complex and well-developed aids such as overhead transparencies, models, demonstration apparatus and instructor experiments should be used to support lectures. Keeping the students involved in the unit presentation will greatly increase their interest thereby increasing their chances of learning.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Safety must always be stressed when working with any kind of chemicals. The instructor can best provide instruction in safety by exhibiting safe practice throughout his presentation and by stressing danger where it is needed.

PRESENTATION:

Nature of Matter: A definition - what all things are made of---whatever occupies space and is perceptible to the senses in some way.

I. Atomic structure
   A. At one time the atom was thought to be the ultimate unit in the subdivision of matter. This is no longer acceptable.
   B. The atom is composed of still smaller units.
   C. To consider all sub-atomic relationships is an impossible task in this unit.
   D. The general structure of the atom is important. For example---
      1. When material is stressed, the attractive forces between atoms resist the stress and keep the materials from deforming and pulling apart.

Demonstration - Large rubber band to be stretched and released

2. Electrical conductivity arises from the mobility of electrons associated with the "parent" atom.

Demonstration - Show the electrical conductivity of metal, glass, and rubber serve as a link to complete the circuits at different times.

3. Heat conductivity is closely associated with electrical conductivity.

E. Make up of the atom
   1. Nucleus
      a. Protons
      b. Neutrons
   2. Orbits, electrons

Transparency #1 - Atomic structure, atomic symbol

F. Size of atom.
   1. No one has ever seen an atom or any parts of the atom.
   2. Scientists, through the electron microscope have been able to trace electron movement by the vapor trails they leave as they move about the nucleus of an atom.

Demonstration - Using the point of a pin as the area, explain that there are millions of atoms just at the point.

3.

$$\text{One grain of copper} = \frac{6.02 \times 10^{23}}{63.54} \text{ atoms}$$

$$\text{Or each pound of copper} = 454 \times \frac{6.02 \times 10^{23}}{63.54} \text{ atoms}$$

Problem Assignment - Have students work out this problem of the number of atoms in a gram of copper. Let them also explore other materials in a similar manner.

G. The charge of an atom
   1. In its normal state the charge of an atom is neutral with the same number of protons and electrons
   2. The proton carries a charge that is equal but opposite to that of an electron

Transparency #2 - Atomic charge

3. If we somehow dislodge an electron from the atom, the electrical charge is unbalanced positive.
4. This electron must associate itself with another atom and if it increases the number of electrons of a balanced atom, that atom becomes unbalanced negative.

II. Valence Electrons

1. All the electrons within an atom are important in understanding the chemical, physical and mechanical properties of metals.
    a. The number of electrons in orbit
    b. The attraction toward the nucleus
2. The important electrons, however, are the valance electrons. Those in the outer shell.
    a. Electrons orbit the nucleus of an atom in what we call quantum shells and subshells.
    b. For simplification we may consider only the quantum shells.
        (1) K The first and lowest energy shell contains 2 electrons when filled.
            L The second contains a maximum of 8
            M The third contains a maximum of 18.
            N The fourth contains a maximum of 32.
        (2) The O-P-Q shells may also exist, but the maximum number of electrons in any of these is 32.
        (3) Atoms are considered to be inert and very stable if the K valence shell has two electrons, and after this, eight seems to make possible a stable element.
        (4) In the case of the noble gases, helium has a valence of 2 in the K shell. It is inert.
        (5) All of the other noble gases have 8 electrons in their valence shell. They are also inert.
        (6) In the case of the group I A metals, the alkali metals, lithium has a valence of 1 in the L shell and 2 in the K shell. All the rest have 1 electron in their valence shell backed up by 8 in the next. All of these metals are very reactive.

Note! Alkali metals are very reactive metals, whose reactiveness can partially be explained by their desire to have their valence electron of 1 removed so that they will then have a stable condition with 8 electrons in their outer orbit.

Transparency #3 - Atomic Numbering and Characteristics of Elements. Hydrogen, Helium, Lithium

II. Table of elements

Chart - Periodic Table of Elements or hand-out sheets of the chart.

A. Of the 103 plus elements which have been discovered thus far, over 60 of them are metals.
B. These metals are grouped according to their similarities.
    1. Group I, subgroup A are the alkali metals. Derived from plant ash, each has one valence electron, backed up by two or eight.
    2. Group II A are the alkaline metals sometimes called alkaline earth metals because they were the first isolated from their earthy oxides. Each has two valence electrons backed up by two and eight. The radius of these atoms are much smaller than those in group I A and their valence electrons are more tightly held. These metals are not very reactive.
    3. The next groups starting with III A are called the first transition metals because these begin the transition from metals to non-metals. Its members tend to be hard and brittle. The transition quality of these elements stem from their peculiar electronic structure. In the case of "typical elements," the number of electrons in the outer orbit goes up as the atomic numbers go up. With the transition metals a rise in atomic number also indicates a rise in electrons, but not in the outer orbit. All the transition metals keep at most two electrons in their outer orbit while their next inner shell "fills up" with electrons. The transition metals are all found in Group IIIA, IVA, VA, VIA, VIIA. Mixed in with these are non-metals which are identified by Group IIIB, IVB, etc.
    4. The second transition metals are called triads because they are grouped in threes. These metals are good mixers. The first triad, iron, nickel and cobalt are all strongly magnetic. They mingle easily and an alloy of these three plus aluminum produces a metal called Alnico which is used in making very strong magnets.
       The next two triads, called the light and heavy platinums are also good mixers. Alloys among the six of them find wide use in jewelry and precious instruments.
       Among the familiar elements, few are closer in their electronic structures than are iron, cobalt, and nickel: each has two electrons in their outer orbits with 14, 15, and 16 electrons respectively in the next inner shell. The two platinum triads are related almost as intimately.

5. The third transition metals are located on the chart of elements as Group IB and IIB in the same column numbers as the alkali and alkaline metals. Copper, silver, and gold (Group IB) are completely opposite the alkali metals. Rather than being light, soft and very reactive, these metals are rather heavy, hard and inert. Though alkali metals are never found free in nature, these transition elements often occur as free nuggets. Yet both groups, IA and IB, have a single electron in the outer orbit of their atoms, and thus ought to show similar chemical properties.
   The key to their differences lies in their next to the last orbit. Most alkali metals have eight electrons in that shell. Eight is the magic octet in electron circles. Hence, the alkali metals react violently to get rid of their one electron to achieve a kind of atomic mirvana. But copper, gold and silver have not eight, but eighteen electrons in their next to the last shell. Even if they get rid of their outer electron, they are still far from the stability of eight. Thus, they are discovered from reaction, which accounts for their appearance in nature in pure form.
6. The Boron Carbon family of elements beginning with Group IIIB contains some ten elements which are both metal and non-metal. No group of elements is so varied as this group. Presumably, this is because they are near the halfway point in the Periodic table; with three or four electrons in their outer shell, they lie squarely between the alkali super metals and the super non-metal halogens. Out of this no-man's land comes man himself and indeed all of life. It is because carbon acts somewhat like a metal and somewhat like a non-metal that it can combine in a fantastic variety of ways.

C. Elements on the Periodic Chart tend to be more metallic toward the left and more non-metallic toward the right.

D. The Roman numerals across the top are called the column numbers and in groups I through VII indicates the number of valence electrons.

E. The numbers down the side of the chart are the row numbers and they indicate the number of shells (orbitals) in the atom.

F. Row numbers 6 and 7 are the Rare Earth metals, uranium being the most familiar. The elements found in these rows are the latest ones to be discovered. Many of them are "man made" and were discovered through atomic research.

Note: There is much information concerning the elements located on the chart of elements. More than we can include in this lesson. A good ready reference would be the "Key to the Periodic Chart of the Atoms," which comes with most charts. If you use the Welch Scientific Chart, they have a key which can be ordered from the Welch Scientific Company.

III. Crystal Bonds and Nature of Interatomic Forces of Attraction.

A. Most materials we use are liquid or solids - some gases.

B. Under normal conditions, the forces of attraction which bond atoms together are strong.

C. Some materials have stronger attraction than others.

Demonstration - Combustion of gasoline, and aluminum powder -- using a combustion apparatus.

(Description of apparatus and explanation:

This apparatus consists of a plastic tube within a tube, both at least 22" high, with the diameter of the inside tube being at least 2" in diameter. A cork stopper should be placed in the inner tube. Both tubes should fit into a base and a small orifice should be extended through the base to the center of the inner tube. A plastic hose should be attached to this orifice and a bulb from a syringe placed on the opposite end. The purpose for the outer tube is for safety. A source of current should be available of at least 6 volts within the base of the small tube provide contact points for an electrical spark.

This apparatus can be used to ignite gasoline or aluminum powder or other finer ground combustible material.

1. Gasoline demonstration: Place three or four drops of gasoline in the inner tube and place the stopper over the top. Allow a few minutes for the gasoline to evaporate into gas. Turn on the current to the spark points. The gas will ignite and the stopper will be blown out of the top.
2. Aluminum Powder demonstration: Take both tubes out of the base. Place a small amount of aluminum powder in the orifice of the base. Return tubes to their proper place. Turn on the current to the sprak points and force air through the small tube with the bulb syringe. The aluminum powder will ignite.

Note: This apparatus can be used to demonstrate that the bonding characteristics of certain materials are quite loose as in the case of gasoline, and that materials which have relatively strong bonding forces can also be broken down by certain treatments such as making aluminum into a powder and atomizing it with forced air.

D. If strong forces of attraction did not exist between metal atoms, metals would deform under small loads and atomic vibration associated with thermal energy would gasify the atoms at low temperatures.

Note: The important thing to remember is that engineering properties of any material depend on the interatomic forces which are present.

E. Interatomic attractions are caused by the electronic structure of atoms.

1. Noble gases (inert or chemically inactive) such as He, Ne, A, etc. have only limited attractions to other atoms because they have a very stable arrangement of electrons (valence). They have no net charge because of this stable configuration. The forces of attraction between these inert atoms to form "molecules" is called Van der Waal forces.
2. Most other elements are trying to achieve the highly stable configuration of having full valence shells through:
   a. Receiving extra electrons
   b. Releasing electrons
   c. Sharing electrons

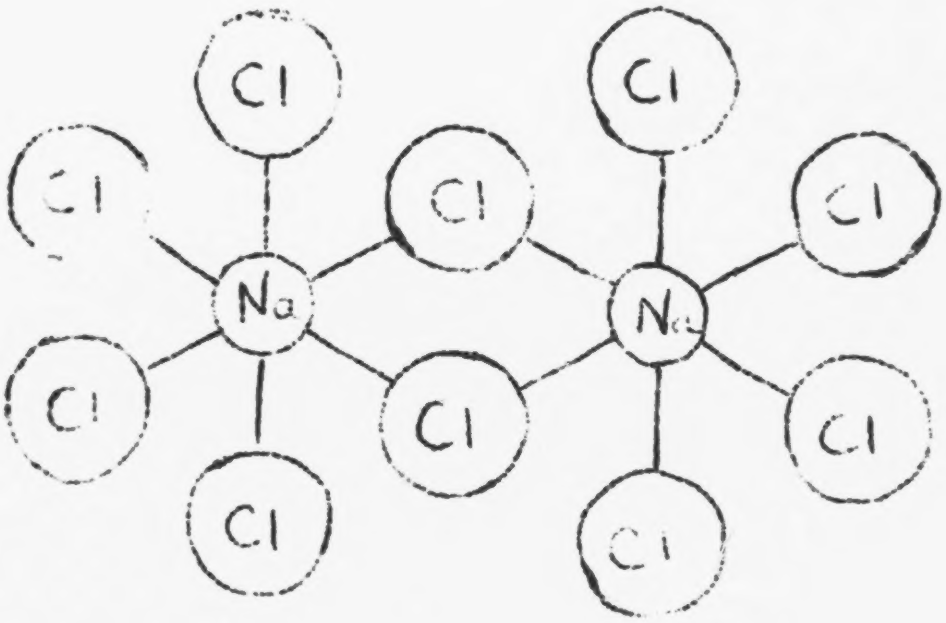
Transparency (2nd time--review) - Atomic Numbering and Characteristics of Elements. Hydrogen, Helium, Lithium

F. Ionic Bonding results from the mutual attraction of positive and negative charges (coulombic attraction)

Transparency #4 - Ionic Bonding

1. This transparency may lead us to expect that ions of Na and Cl would join up in pairs. If this is all that would happen there would be very little attraction between these pairs and others in the compound. We would not have solid NaCl as we know it.
2. Actually, a negative charge possesses an attraction for all positive charged particles and a positive charged particle has an attraction for all negatively charged particles. The number of positive charges equal to the number of negative charges.

Demonstration - model of NaCl structure. Use styrofoam balls of different colors and sizes. The Na atom should be smaller than Cl. Build this model symmetrically using the following illustration:

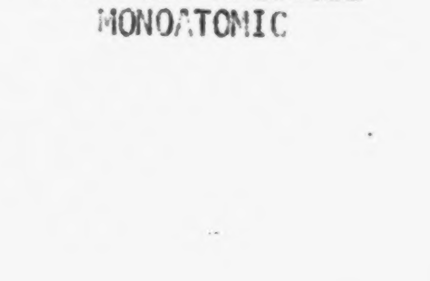


ATOMIC MODEL
OF NaCl CRYSTAL

G. Co-valent bonds -- an atom acquires its stable configuration of eight valence electrons by sharing its valence electrons with an adjacent atom. (In the case of hydrogen, 2 is stable configuration)

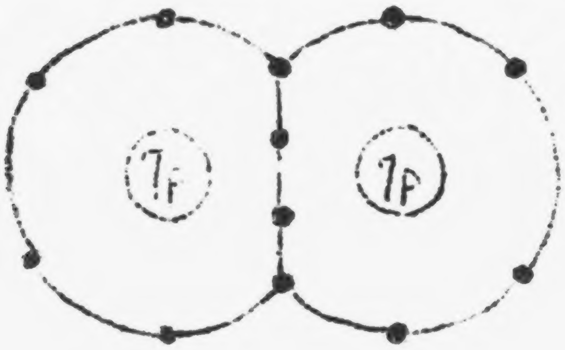
1. Hydrogen molecule (monoatomic)

Illustration, chalk board.



HYDROGEN MOLECULE
MONOATOMIC

2. Oxygen Molecules (Diatomic)



7e + sharing of 1 = 8e

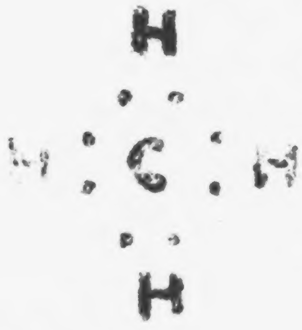
OXYGEN MOLECULE
DIATOMIC

- a. A closer bond is produced as more electrons are shared
- b. An oxygen molecule is more stable than hydrogen.

3. Different elements forming co-valent bonds (Polyatomic)
   - a. Atoms do not have to be of the same element to form co-valent bonds.
   - b. One carbon atom surrounded by four hydrogen atoms (methane)

Illustrate, chalk board.

4 H with a valence of 1 each = 4 electrons
C with a valence of 4 = 4 electrons



METHANE

Demonstration - Methane Atomic Model Co-valent Bonds (Trans. #5)

4. The Diamond is a co-valent bond which accounts for the great hardness of the material. The covalent bond is the strongest of all. Hence, materials with this arrangement are reluctant to change their structure.

H. Metallic Bonds - valence electrons of some elements, when only a few (electrons) are involved, are relatively easy to remove from orbit of their "parent" atom. The balance of the electrons below the outer orbit are held firmly to the nucleus.

Transparancy #6 - Metallic Bonds

1. This forms a structure of positive ions and free electrons.
2. The positive "ion cores" consist of the nucleus and the non-valence electrons.
3. Because the valence electrons are free to move about within the metal structure, they form what is frequently described as an electron "cloud" or gas.
4. The positive ions and the negative electron "cloud" provide attractive forces which bond the metal atom together.
    a. The crystalline array of atoms in a solid metal helps to determine the metals mechanical properties.
    b. The free electrons give the metal its characteristically high electrical conductivity, since they are free to move in an electric field.
    c. The high thermal conductivity of metals is also associated with mobility of the valence electrons which can transfer thermal energy from a high to a low temperature level.
    d. Free electrons in the metal absorb light energy so that all metals are opaque to transmitted light.

IV. Space Lattice and Crystal Structure

A. Space lattice or crystal lattice is atom arrangement which has repeating patterns in three dimensions.
B. This repeating pattern is due to atomic coordination within the material.
C. The pattern also controls the external shape of the crystal as in the case of a snow flake which has a six pointed outline.

D. Types of space lattices. There are 14 possible types of space lattices and they fall into seven crystal systems found illustrated on the Periodic Chart. Most metals crystallize in either the cubic or hexagonal systems and only three types of space lattices are commonly encountered
   1. Body-centered cubic (B.C.C.) - contains one atom at each corner of a cube and one in geometric center. Tungsten, chromium, alpha iron, delta iron, molybdenum, vanadium and sodium.
   2. Face-centered cubic (F.C.C.) - an atom at each corner of a cube and one at the center of each face. Aluminum, nickel, copper, gold, silver, lead, platinum, and gamma iron.
   3. Close packed hexagonal (C.P.H.) - two basal planes in the form of regular hexagons with an atom at each corner of the hexagon and one atom at the center. There are also three atoms in the form of a triangle midway between the two basal planes.
      a. A portion of each one of these lattice arrangements forms a unit cell.
      b. When many of these unit cells come together we have the formation of a crystal, or in the case of metals, we have grain formation.

E. Miller indices - Slip planes.
   1. The layers of atoms or the planes along which atoms are arranged are known as atomic or crystallographic planes.
   2. The relation of a set of planes to the axes of the unit cell is designated by Miller indices.
   3. One corner of the unit cell is assumed to be the origin of the space coordinates, and any set of planes is identified by the reciprocals of its intersections with these coordinates.

Demonstration - Slippage of Atoms (Slip planes)
Procedure - place several steel balls (1/8" dia.) in a plastic box with a small amount of mineral oil. Place on the overhead projector. Make sure that there is only one layer of these balls on the bottom of the plastic box and that they are touching each other. Apply pressure to the mass of balls and watch the screen to see slippage occur.

F. Defects in crystals - as metals crystallize the activity that is occuring in the surface is quite extensive.
   1. If the crystal should grow at a very slow rate, such as 1 mm per day, it would require deposition of some 100 layers of atoms per second on the surface.
   2. All of these atoms must be laid down in exactly the right order for the crystal to be perfect. It is not suprising then that few crystals are perfect. The important crystal imperfections are:
      a. Vacancies - empty atom sites.
      b. Interstitial - atom moves out of an orderly arrangement.
      c. Dislocation - a disturbed region between two substantially perfect parts of a crystal.

G. Analysis of crystals by means of x-ray diffraction.
   1. Because few crystals are found formed under conditions permitting the full development of the faces, perfectly formed crystals, particularly in metals, cannot be obtained. Therefore, it is necessary to utilize x-rays or other very short wave length rays, such as beams of electrons or neutrons, for studying the structure of crytals, particularly their inner structure. Inasmuch as the atomic spacings in crystals are only a few Angstroms, it is understandable that x-rays might play an important part in the study and research of crystal structures.
      a. A beam of x-rays is diffracted from a crystal.
      b. The diffraction pattern can be studied and analyzed to give size, shape and orientation of the unit all of the crystal. This is done mainly by examining and analyzing the intensities of the reflected x-ray beams. The most accepted method of doing this is by using the structure-factor equation, which bears a relationship between the position of each atom and the intensities of all reflections.

H. Grain Growth
   1. Grain growth is determined by the recrystallization of metal as it freezes.
   2. It also can be determined by the heat treating processes.

a. Large grains can be grown by holding the metal at a temperature just below the melting point for a long period of time. (This temperature is where maximum grain growth will take place.

b. Fine grains can be grown by slowly heating metal well below the melting point.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Students should do outside reading and independent study to keep up with this presentation. They should be involved with certain lab experiments designed to support the information given in lecture.

UNIT EVALUATION:

Unit test should be made out and presented by the teacher who presents the unit. The teacher should also encourage discussion with the students. Observation of students' attitute toward the unit should help in the evaluation.

DEFINITION OF TERMS:

1. Neutral Atom (balanced) - The charges of an atom are equal. Same number of protons as electrons.
2. Unbalanced atom - Atom has lost or gained electrons.
3. Unstable atom - an atom which desires to lose or gain electrons so that its valence orbit will be completely filled.
4. Stable atom - an atom which has lost or gained electrons in order to fill its outer orbit.
5. Magic octet - Eight electrons in the outer orbit of an atom.
6. Ion - an atom which has either lost (positive) or gained (negative) electrons.

REFERENCES:

STUDENT:

1. Elements of Materials Science, Addison-Wesley Pub. Co., Reading, Mass.
2. Material Science in Engineering, Charles E. Merrill Pub. Co., Columbus, Ohio.

TEACHER:

1. Principles of Modern Metallurgy, Charles E. Merrill Pub. Co., Columbus, Ohio.
2. Introduction to Physical Metallurgy, McGraw-Hill Book Co., New York, N.Y.
3. Materials, Scientific American Book, W.H. Freeman and Co., San Francisco, Calif.
4. ASTM Handbook, American Society for Testing Materials.
5. Key to Understanding the Periodic Chart, Welch Scientific Co.,

EXPERIMENT #1 - CRYSTALLINE GROWTH

Problem: The reasons for doing this experiment is to actually see the growth of crystals.

Equipment needed:

1. Laboratory microscope under 100x with light source for tops of slide.
2. Hot air blower with tube connected to the blower end of concentration of air to one spot on the slide.

Materials needed:

1. Small bottle of copper sulphate, or other solutions such as sodium chloride.
2. Eye droper
3. Microscope slide

Safety:

1. This is a very safe experiment, with the exception of damage that might occur to the microscope. Some microscopes have oil emersion lenses and should not be heated. Care should be taken to insure that no heat is directed toward the lense.
2. These salt solutions are very corrosive and care should be taken to insure that this material is not allowed to corrode the equipment.
3. Standard laboratory safety should always be in practice as experiments are conducted.

Procedure:

1. Select a magnification of 40x and place a single glass slide on the microscope table.
2. Arrange the hot air blower so that the hot air is directed down toward the table and on top of the slide.

3. Place a drop of copper sulphate on the slide under the lens.
4. Focus the microscope on the drop of fluid.
5. Turn on the blower and be sure it is directed on the fluid.
6. Observe through the eye piece the formation of crystals as the liquid dries up leaving the crystals behind.

Questions to be answered:

1. Can the crystal growth be seen?
2. What happens when one crystal makes contact with another which is forming?
3. How can this growth be compared with crystalline growth in metals ?

EXPERIMENT #2 - MICROSCOPIC EXAMINATION OF METAL CRYSTALS

Problem: This experiment is conducted to show the similarity of metal crystal growth between crystals of other materials such as those developed in experiment #1 of this unit.

Equipment:

1. Metallography microscope
2. Polishing (specimen) machine
3. Specimen mounting materials or equipment

Materials needed:

1. Specimens of different kinds of metal
2. Etchants for microscopic examination

Safety:

1. Be especially careful with this equipment, especially the microscope.
2. The etching reagents are especially harmful because they are acids - normal protective measures such as goggles, rubber aprons, and rubber gloves are needed for this experiment.

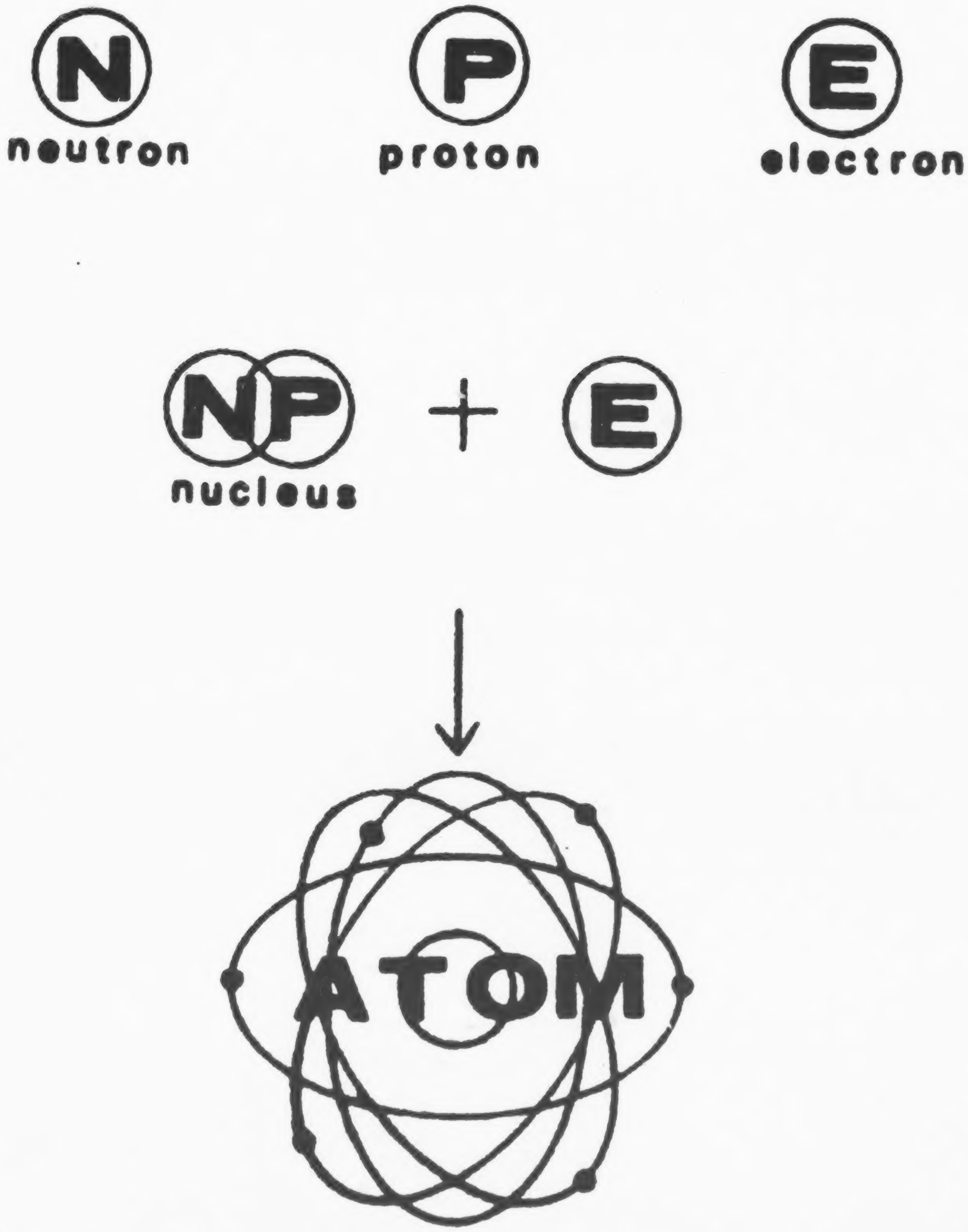
Procedure:

1. Set up the microscope for 500x (this may vary).
2. Polish and etch the metal samples. Be sure to wash the reagent from the specimen before placing on the microscope table.
3. Focus and loop at each specimen.

Questions to be answered:

1. What are the similarities of these crystals and the copper sulphate crystals?
2. What are the differences?
3. How do the crystals of each specimen compare with the others which you are using?

MATTER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P
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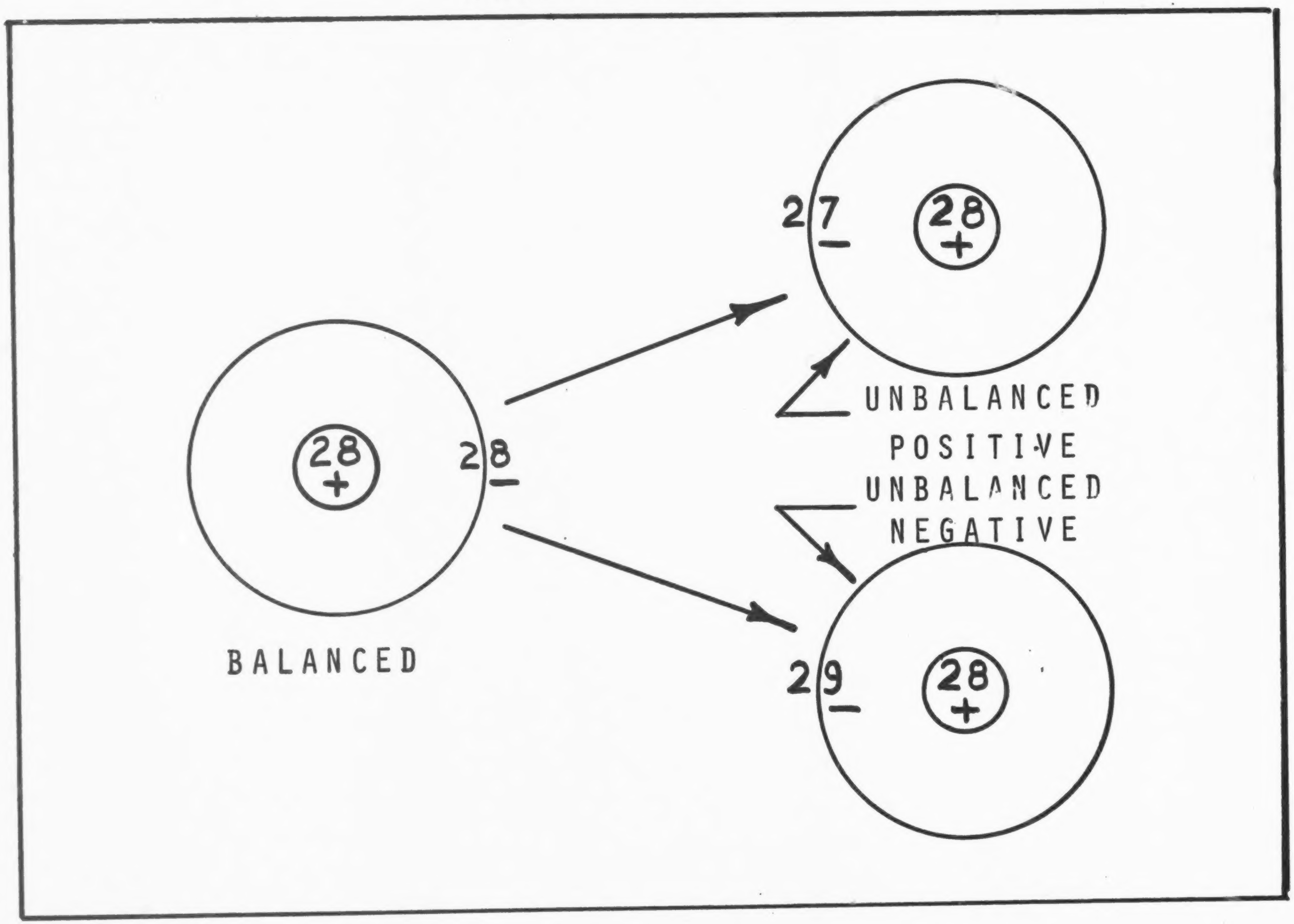
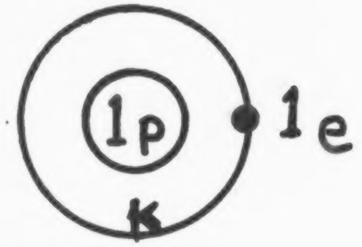
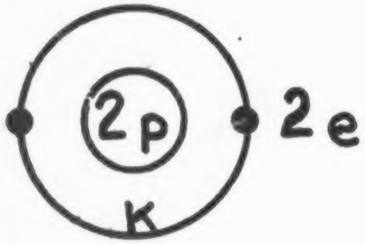
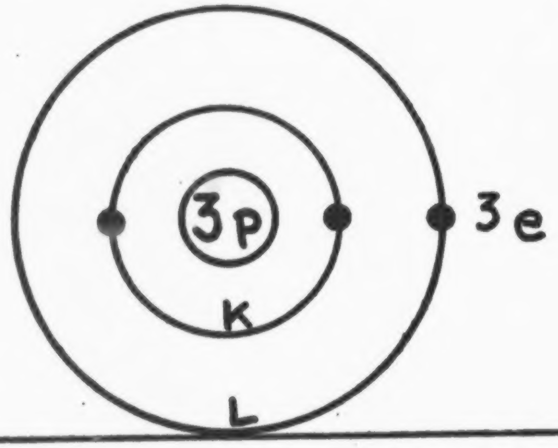
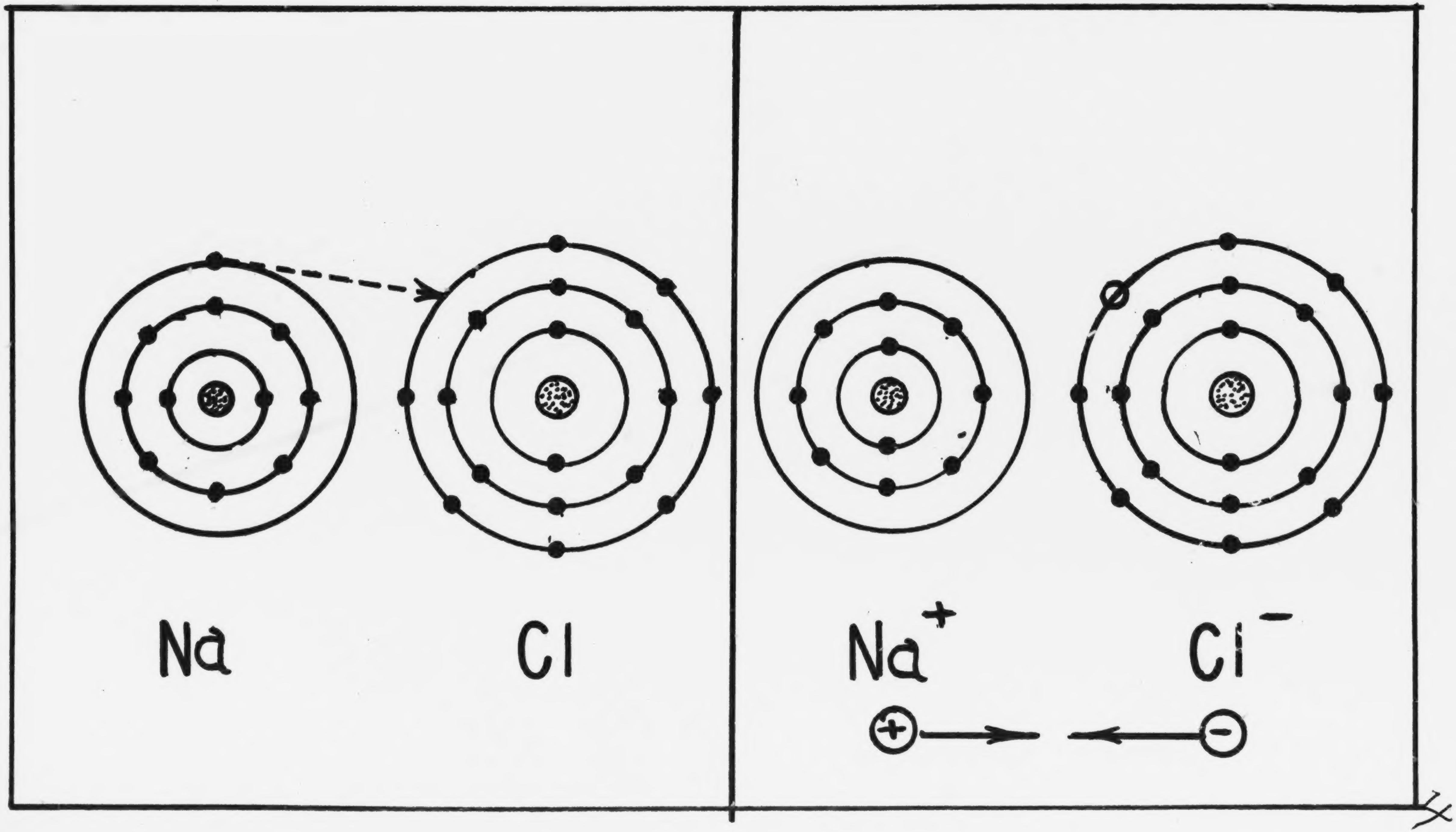
E
electron
NP
nucleus
+
E
ATOM

ATOMIC CHARGE

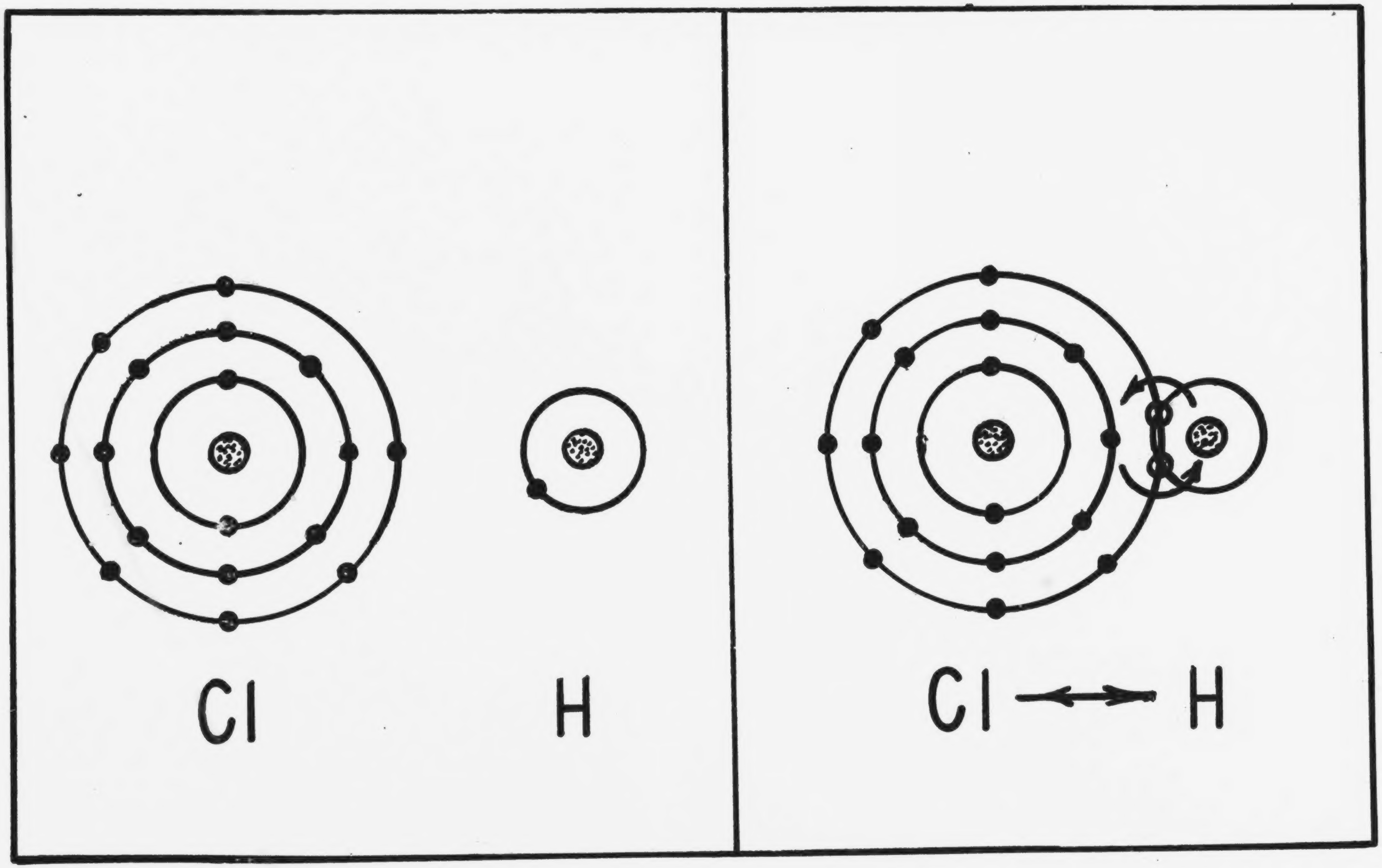

28 +
28 −
BALANCED
27 −
28 +
UNBALANCED POSITIVE
UNBALANCED NEGATIVE
29 −
28 +

CHARACTERISTICS		ELEMENT	ATOMIC NUMBER
REACTIVE GAIN 1 ELECTRON		HYDROGEN	1
INERT		HELIUM	2
REACTIVE LOSE 1 ELECTRON		LITHIUM	3

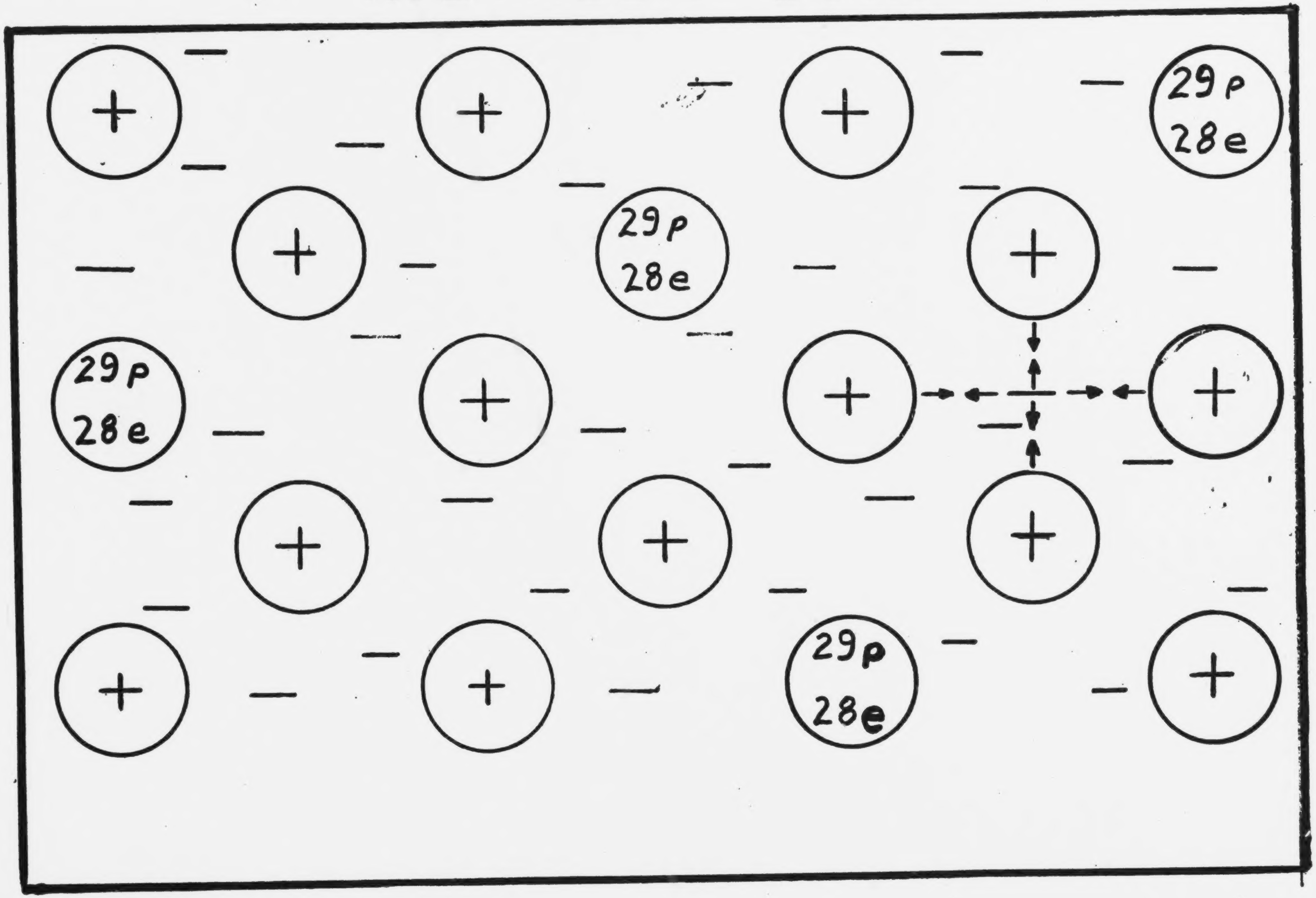
IONIC BOND



COVALENT BOND



METALLIC BOND


29p
28e
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SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Buster K. Ichikawa
Roosevelt Junior High School
San Jose, California

INSTRUCTIONAL LEVEL: Junior High

TITLE: Thermal Conductivity of Metals

PRESENTATION TIME: Two periods

INTRODUCTION:

Thermal conductivity is one of the important properties of metal. Designers must select the metal which best meets the particular requirements of a product. At times this may have to be a material which will transfer heat readily. In other instances the designer may want a somewhat insular material. This unit will show the student that there is a different rate of heat conductivity for different metals.

OBJECTIVES:

1. To show the comparative conductivity of different metals.
2. To understand the molecular interaction in heat conductivity.
3. To give students experience in plotting a graph.
4. To give students experience in lab experiment techniques.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Metal

INTER-RELATION WITH OTHER SUBJECTS:
Science
Electricity

USE IN INDUSTRY:

A thorough understanding of thermal conductivity is a must in the industries. For example, the fuel cells of nuclear reactors must be clad to prevent corrosion and to keep radioactive particles from entering the coolant. This is not a desirable situation from a heat-transfer standpoint and therefore the material selected must be as thin as possible and of the best possible heat conductivity.

MATERIALS AND EQUIPMENT:

1. Bunsen burner
2. Beaker
3. Thermometer
4. Asbestos
5. Various Test Metals - 1/4" x 5" sq.
6. Overhead Projector

EDUCATIONAL MEDIA:

1. Lecture-demonstration
2. Transparencies
3. Lab Work Sheet
4. Student Experiments

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

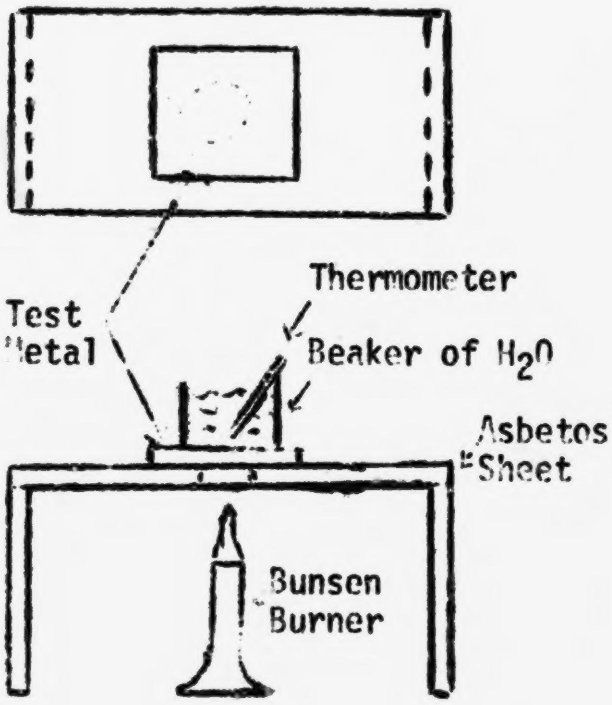
SAFETY:

Precaution for burns

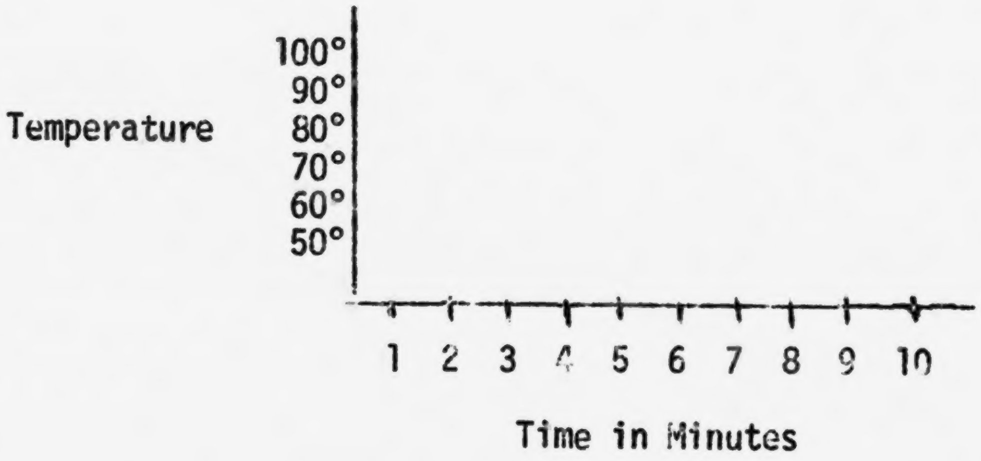
PRESENTATION:

- I. Three basic methods of heat transfer
  - A. Conduction - from molecule to molecule - metals, basically.
  - B. Convection - movement of heated matter from one place to another - liquids and gases.
  - C. Radiation - heat waves, no matter necessary - solar.
- II. Thermal Conductivity
  - A. Analogy: Like water seeks its own level, heat is transferred from hot to cold until it reaches a temperature uniformity.
  - B. When there is heat inequality, there is a net transfer of thermal energy from warmer to colder region.
  - C. All substances are composed of tiny particles called molecules and these molecules are in constant motion or vibration.
  - D. Heat conduction occurs by the interaction of molecules.
  - E. As molecules become hot, they move more rapidly and strike the molecule next to them. In turn these strike the molecules next to them and causes adjoining molecules to move faster thereby getting hotter.
  - F. Diversity of thermal conductivity especially at low temperature is because of crystal imperfections.

III. Experiment



1. Cut several different metals of the same guage into 5" squares. (Iron, brass, copper, aluminum, etc.)
2. Center a test metal over hole in asbestos sheet.
3. Place a beaker of measured water on test metal.
4. Place a thermometer in beaker of water.
5. Important - prior to each test the beaker, water and thermometer must commence at the same temperature. This can be accomplished by cooling with running water.
6. Light and adjust flame of bunsen burner. (Heat must be constant for all tests). Place under opening.
7. At regular intervals, note the reading on the thermometer until the reading reaches a given temperature (100° F.)
8. Test and compute other metals in the same way.
9. Plot the readings on a temperature-time chart.



10. This will give a comparative test on the heat conductivity of the metals tested.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

1. Lab Work Sheet
2. Questions to be answered during experiment
    a. Why must the test metals be the same size and of the same guage?
    b. Why must the water in the beaker be measured?
    c. Why must the source of heat be constant for all tests?
    d. List the order of conductivity of metals tested.
    e. How is heat transferred through the metals?
    f. Are molecules a rigid, immobile particle in the metal?
3. Unit exam

UNIT EVALUATION:

1. Observation during experiment
2. Evaluation of question sheet
3. Test on unit
4. Subjective evaluation by teacher

DEFINITION OF TERMS:

1. Conduction - heat through molecular interaction
2. Convection - heat by mass movement of heated particle.
3. Radiation - heat in form of rays, i.e. solar.

REFERENCES:

STUDENT:

The World Book Encyclopedia

TEACHER:

1. The World Book Encyclopedia
2. Concom, E. U. and Odisham, Hugh, Handbook of Physics.
3. Halliday - Resnick, Physics for Students of Science and Engineering
4. McGraw-Hill, Encyclopedia of Science and Technology.
5. Van Nostrand's, Scientific Encyclopedia, 3rd Ed.

FOREST PRODUCTS

INDUSTRIAL MATERIALS STUDY

Course Outline

FOREST PRODUCTS

Forest products may be defined as "any material which is either grown or made from fiberous material located in the forest."

I. Wood
  - A. History
  - B. Location
  - C. Selectivity
  - D. Identification
  - E. Characteristics and uses
  - F. Properties

II. Plywood
  - A. History
  - B. Identification
  - C. Characteristics and uses
  - D. Properties

III. Fiberboard
  - A. Classification
  - B. Description and uses
  - C. Manufacture

IV. Hardboards - physical properties - uses
  - A. Fibrous
  - B. Resin - bonded particle
  - C. Special densified
  - D. Treated
  - E. Untreated
  - F. Manufacture

V. Insulation board, rigid
  - A. Accoustical board
  - B. General use board
  - C. Interior board
  - D. Roof insulation
  - E. Sheating board

  - F. Manufacture

VI. Laminates
  - A. Laminated construction - def.
  - B. Advantages of laminates
  - C. Methods of producing
  - D. Uses
  - E. Paper base
    - 1. High strength (papreg)
    - 2. Lignin - filled
  - F. Manufacture

VII. By-Products

- A. Pulp - mainly coniferous woods used. Cellulose pulp prepared in digestion by chemical action.
  1. Sulfides (process)
  2. Sulfates (process)
  3. Sodas (process)
  4. Semi-chemical (process)
  5. Ground-wood or mechanical pulp - wood ground against special stones (from hard or soft wood)
  6. Used for paper, insulation board, cord-rope, onion skin, lacquers, explosives, photo film, glassine paper, etc.
  7. Residues used in the making of adhesives, core bonder, methyl alcohol, pen oil, turpentine and acetone.
- B. Wood Distillation - processes) wood is carbonized in absence of air to give charcoal and volatile products
  1. Acetic Acid
  2. Acetone
  3. Charcoal
  4. Methoniol
  5. Pitch
  6. Tar oil
  7. Cedar oils
  8. Cresote
  9. Oils
  10. Dipentine
  11. Lacquer solvents
  12. Pine oils
  13. Pine tars
  14. Resins
  15. Wood turpentine, etc.
- C. Wood Hydrolysis
  1. Different woods for specific extracts
  2. Treating with water and other solvents to dissolve out extracts.
  3. Some products of wood hydrolysis
     - a. Acetic acid
     - b. Bakery yeast
     - c. Butadiene
     - d. Carbonic acid
     - e. Ethyl alcohol
     - f. Animal feed
     - g. Turfurural
     - h. Glycerene
     - i. Lignin powder
     - j. Sugars
- D. Wood Condensation
  1. Turfural
  2. Soil conditioner
- E. Alkaline Fusion
  1. Exalic Acid
  2. Pyregallel
  3. Resins

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Earl Woolcott
Slocume Truax Junior High
Trenton, Michigan

INSTRUCTIONAL LEVEL: Junior High

TITLE: Adhesives in Woodworking

PRESENTATION TIME: 30 min.

INTRODUCTION:

Adhesives could be very easily misconstrued as a simple study of glue, but the area covered by this material is vast. Adhesives are quite often defined as any substance capable of holding two or more materials together. We often find materials, environment, undergo degrees of chemical and/or physical change, occasionally rejecting the adherant. It is, therefore necessary to understand the mechanism of adhesion as well as the adhesive.

OBJECTIVES:

1. To show the mechanical aspects of adhesives
2. To show the effects of the environmental conditions on glued joints
3. To expose the student to the chemistry of adhesives
4. To show the need for proper selection of an adhesive

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Woodworking

INTER-RELATION WITH OTHER SUBJECTS:

A substance capable of holding two materials together by surface attraction is an adhesive. The surface attraction is a result of molecular force of attraction. With this background there are a number of subject areas involved such as Metals, Plastics, Ceramics, Coatings, Textiles, Fabrics, Power Mechanics, and Electricity. Chemistry, Science, and Physics, are involved through the study, development, and testing of adhesive properties.

USE IN INDUSTRY:

Overhead transparency #1A.

MATERIALS AND EQUIPMENT:

1. pre selected wood samples
2. mixing containers and stirring rods
3. large plastic pan
4. clamps
5. a number of adhesives
6. eastman's 910 glue
7. two pieces of glass
8. testing equipment (tensile, shear, impact)
9. overhead projector

EDUCATIONAL MEDIA:

1. film: Glues and Clamps, Series #12
   Michigan State University
   Audio-Visual Dept
   East Lansing,Michigan
2. handout sheet
3. overhead transparencies
4. demonstrations units

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

Care should be observed while using Eastmen's 910 glue.

PRESENTATION:

1. Define adhesives.
2. Overhead #2A. Discuss wetting, adhesion, and cohesion. Demonstrate wetting with Eastman's 910 glue. Glue two pieces of glass together while on the overhead projector.
3. With a variety of adhesives glue thin pieces of stock together and soak in water.
4. OT#10,11,12 &.16Discuss: ionic bond, covalent bond, metallic bond, vanderwall forces.
5. Overhead #4A - discuss the effects of heat, moisture, and dryness.on a glue joint.
6. Overhead #5A. common woodworking glues.
7. Discuss the composition of adhesives.
8. How to select an adhesive (handout)
   a. Compatability with the surfaces including their physical and chemical nature to assure effective wetting.

  b. Match the co-efficients of expansion of the materials to be bonded as closely as possible.
  c. Know the equipment that is necessary to disperse and/or apply the adhesive.
  d. The type of bonding that is being accomplished
  e. Time span between application and drying
  f. The conditions to which the joint will be subjected during it's life span.

9. Demonstrate and discuss the strength of glued joints.
  a. results of glued stock in water
  b. tensile strength test
  c. shear test
  d. impact test

10. Overhead transparencies of 6A are included so the user may supplement as he sees fit.

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

1. Using various adhesives and common materials (adherends), students could very easily review adhesives with reference to their wetting characteristics, setting time, film characteristics and other properties that would enable them to better understand these materials and thus do an adequate job of selecting an adhesive. Metals, woods, and other materials samples should be available for the student to carry out his experiments.
2. Bonded samples could be developed and exposed to high and low temperatures. The humidity aspect could be a fully submerged condition to a controlled humidity condition. These samples should be tested while they are in their environmental condition. This would give a more complete review of adhesives.
3. The student should be made aware of impact strength, shear strength, tensile strength, peel resistance; these are discussed in ASTM Standards on Adhesives, 1967, Book #16. If this book is not available, the teacher should demonstrate how these tests could be accomplished.
4. The student should be made aware of the availability of information on the school or shop library so they may do further research.

UNIT EVALUATION:

(sample ten question true-false quiz)

1. Casein is a commonly used ship building adhesive.
2. Adhesion takes place at the surface of the adhesive and adherend.
3. Cohesion takes place at the glue surfaces
4. A disadvantage of epoxy is the drying time
5. All adhesives must be liquid at some time in their life.
6. All glued joints must be clamped until dry.
7. Water is a good wetting agent
8. The shear resistance of an adhesive is important to the furnitute industry.
9. Solvent release takes place by absorption when gluing wood.
10. Weldwood plastic resin can be used to bond metal together.

DEFINITION OF TERMS:

see attached sheet

REFERENCES:

STUDENT:

Cabinetmaking and Millwork - John L. Ferier
Chas. A. Bennett Co., Inc. Peoria, Ill. 1967
Handbook of Adhesives - Irving Skeist
Reinhold Publishing Corp. New York, NY 1962

TEACHER:

A.S.T.M. STANDARDS, Book 16. Wood Adhesives.
American Society for Testing Materials, 1916 Race St. Philadelphia, Pa. 1967
Treatise on Adhesion and Adhesives - Robert Patrick,
Marcel Dekker, Inc. 95 Madison Ave. NyNy. 1966
Adhesion & Adhesives - Parker & Taylor
Pergamon Press, Ltd. 4401 21st St. Long Island City, NY. 1966
Adhesive Raw Material Handbook - McGuire.
Padric Pub Co. Mountainside, New Jersey.

DEFINITIONS OF TERMS

Some Standard Definitions of Terms Relating to Adhesives.

Adhere, v. - To cause two surfaces to be held together by adhesion.

Adherend, n. - A body which is held to another body by an adhesive.

Adhesion, n. - The state in which two surfaces are held together by interfacial forces which may consist of valence forces or interlocking action, or both.

Adhesion, Mechanical - Adhesion between surfaces in which the adhesive holds the parts together by interlocking action.

Adhesion, Specific - Adhesion between surfaces which are held together by valence forces of the same type as those which give rise to cohesion.

Adhesive, n. - A substance capable of holding materials together by surface attachment.

Note: Adhesive is the general term and includes among others cement, glue, mucilage and paste. All of these terms are loosely used interchangeably. Various descriptive adjectives are applied to the term adhesive to indicate certain characteristics as follows:

Physical form, that is, liquid adhesive, tape adhesive.
Chemical type, that is, silicate adhesive, resin adhesive.
Materials bonded, that is, paper adhesive, metal-plastic adhesive, can label adhesive.
Conditions of use, that is, hot-setting adhesive.

Adhesive, Cold-Setting - An adhesive which sets at temperatures below 20°C (68°F)

Adhesive, Hot-Setting - An adhesive which requires a temperature at or above 100°C (212°F) to set it.

Adhesive, Pressure-Sensitive - An adhesive made so as to adhere to a surface at room temperature by briefly applied pressure alone.

Adhesive Dispersion - A two-phase system in which one phase is suspended in a liquid.

Binder, n. - A component of an adhesive composition which is primarily responsible for the adhesive forces which hold two bodies together.

Blister, n. - An elevation of the surface of an adherend, somewhat resembling in shape a blister on the human skin; its boundaries may be indefinitely outlined and it may have burst and become flattened.
Note: A blister may be caused by insufficient adhesive; inadequate curing time, temperature or pressure; or trapped air, water, or solvent vapor.

Bond, n. - The union of materials by adhesives.

Bond, v. - To unite materials by means of an adhesive.

Bond Strength - The unit load applied in tension, compression, flexure, peel, impact, cleavage, or shear, required to break an adhesive assembly with failure occurring in or near the plane of the bond.
Note: The term adherence is frequently used in place of bond strength.

Catalyst, n. - A substance which markedly speeds up the cure of an adhesive when added in minor quantity as compared to the amounts of the primary reactants.

Cohesion, n. - The state in which the particles of a single substance are held together by primary or secondary valence forces. As used in the adhesive field, the state in which the particles of the adhesive (or the adherend) are held together.

Cold Flow - See Creep

Cold Pressing - A bonding operation in which an assembly is subjected to pressure without the application of heat.

Condensation, n. - A chemical reaction in which two or more molecules combine with the separation of water or some other simple substance. If a polymer is formed, the process is called polycondensation.

Consistency, n. - That property of a liquid adhesive by virtue of which it tends to resist deformation.
Note: Consistency is not a fundamental property but is comprised of viscosity, plasticity, and other phenomena.

Crazing, n - Fine cracks which may extend in a network on or under the surface of or through a layer of adhesive.

Creep, n. - The dimensional change with time of a material under load, following the initial instantaneous elastic or rapid deformation. Creep at room temperature is sometimes called Cold Flow.

Cure, v. - To change the physical properties of an adhesive by chemical reaction, which may be condensation, polymerization, or vulcanization; usually accomplished by the action of heat and catalyst, alone or in combination, with or without pressure.

Diluent, n. - An ingredient, usually added to an adhesive to reduce the concentration of bonding materials.

Doctor-Bar or Blade - A scraper mechanism which regulates the amount of adhesive on the spreader rolls or on the surface being coated.

Doctor-Roll - A roller mechanism which is revolving at a different surface speed, or in an opposite direction, resulting in a wiping action for regulating the adhesive supplied to the spreader roll.

Elastomer, n. - A material which at room temperature can be stretched repeatedly to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length.

Extender, n. - A substance, generally having some adhesive action, added to an adhesive to reduce the amount of the primary binder required per unit area.

Filler, n. - A relatively nonadhesive substance added to an adhesive to improve its working properties, permanence, strength, or other qualities.

Glue, n. - Originally, a hard gelatin obtained from hides, tendons, cartilage, bones, etc., of animals. Also, an adhesive prepared from this substance by heating with water. Through general use, the term is now synonymous with the term "adhesive."

Gum, n. - Any of a class of colloidal substances, exuded by or prepared from plants, sticky when moist, composed of complex carbohydrates and organic acids, which are soluble or swell in water.
Note: The term gum is sometimes used loosely to denote various materials that exhibit gummy characteristics under certain conditions; for example, gum balata, gum benzoin, and gum asphaltum. Gums are included by some in the category of natural resins.

Hardener, n. - A substance or mixture of substances added to an adhesive to promote or control the curing reaction by taking part in it. The term is also used to designate a substance added to control the degree of hardness of the cured film.

Inhibitor, n. - A substance which slows down chemical reaction. Inhibitors are sometimes used in certain types of adhesives to prolong storage or working life.

Joint, Starved - A joint which has an insufficient amount of adhesive to produce a satisfactory bond.
Note: This condition may result from too thin a spread to fill the gap between the adherends, excessive penetration of the adhesive into the adherend, too short an assembly time, or the use of excessive pressure.

Mechanical Adhesion - See Adhesion, Mechanical, and Adhesion, Specific.

Modifier, n. - Any chemically inert ingredient added to an adhesive formulation that changes its properties.

Monomer, n. - A relatively simple compound which can react to form a polymer.

Mucilage, n. - An adhesive prepared from a gum and water. Also in a more general sense, a liquid adhesive which has a low order of bonding strength.

Paste, n. - An adhesive composition having a characteristic plastic-type consistency, that is, a high order of yield value, such as that of a paste prepared by heating a mixture of starch and water and subsequently cooling the hydrolyzed product.

Penetration, n. - The entering of an adhesive into an adherend.
Note: This property of a system is measured by the depth of penetration of the adhesive into the adherend.

Plasticity - A property of adhesives which allows the materials to be deformed continuously and permanently without rupture upon the application of a force that exceeds the yield value of the material.

Plasticizer, n. - A material incorporated in an adhesive to increase its flexibility, workability, or distensibility. The addition of the plasticizer may cause a reduction in melt viscosity, lower the temperature of the second-order transition, or lower the elastic modulus of the solidified adhesive.

Polymer, n. - A compound formed by the reaction of simple molecules having functional groups which permit their combination to proceed to high molecular weights under suitable conditions. Polymers may be formed by polymerization (addition polymer) or polycondensation (condensation polymer). When two or more monomers are involved, the product is called a copolymer.

Polymerization, n. - Chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance. When two or more monomers are involved, the process is called copolymerization or hetero-polymerization.

Primer - A coating applied to surface, prior to the application of an adhesive to improve the performance of the bond.

Resin, n. - A solid, semisolid, or pseudosolid organic material which has an indefinite and often high molecular weight, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures concoidally.

Self-Vulcanizing, adj. - Pertaining to an adhesive which undergoes vulcanization without the application of heat.

Set, v. - To convert to an adhesive into a fixed or hardened state by chemical or physical action, such as condensation, polymerization, oxidation, vulcanization, gelation, hydration, or evaporation of volatile constituents.

Shortness, n. - A qualitative term that describes an adhesive that does not string, cotton, or otherwise form filaments or threads during application.

Sizing, n. - The process of applying a material on a surface in order to fill pores and thus reduce the absorption of the subsequently applied adhesive or coating or to otherwise modify the surface properties of the substrate to improve the adhesion. Also, the material used for this purpose. The latter is sometimes called Size.

Strength, Dry - The strength of an adhesive joint determined immediately after drying under specified conditions or after a period of conditioning in the standard laboratory atmosphere.

Strength, Wet - The strength of an adhesive joint determined immediately after removal from a liquid in which it has been immersed under specified conditions of time, temperature, and pressure.
Note: The term is commonly used alone to designate strength after immersion in water. In the latex adhesives the term is also used to describe the joint strength when the adherends are brought together with the adhesive still in the wet state.

Temperature, Curing - The temperature to which an adhesive or an assembly is subjected to cure the adhesive.
Note: The temperature attained by the adhesive in the process of curing it (adhesive curing temperature) may differ from the temperature of the atmosphere surrounding the assembly (assembly curing temperature.)

Temperature, Drying - The temperature to which an adhesive on an adherend or in an assembly or the assembly itself is subjected to dry the adhesive.
Note: The temperature attained by the adhesive in the process of drying it (adhesive drying temperature) may differ from the temperature of the atmosphere surrounding the assembly (assembly drying temperature).

Temperature, Setting - The temperature to which an adhesive or an assembly is subjected to set the adhesive.
Note: The temperature attained by the adhesive in the process of setting it (adhesive setting temperature) may differ from the temperature of the atmosphere surrounding the assembly (assembly setting temperature).

Thermoplastic, adj. - Capable of being repeatedly softened by heat and hardened by cooling.

Thermoplastic, n. - A material which will repeatedly soften when heated and hardened when cooled.

Thermoset, adj. - Pertaining to the state of a resin in which it is relatively infusible.

Thermoset, n. - A material which will undergo or has undergone a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., leading to a relatively infusible state.

Thermosetting, adj. - Having the property of undergoing a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., leading to a relatively infusible state.

Thinner, n. - A volatile liquid added to an adhesive to modify the consistency or other properties.

Viscosity, n. - The internal frictional resistance of an adhesive to flow when that resistance is directly proportional to the applied force.
Note: Viscosity and consistency are erroneously used interchangeably.

Vulcanization, n. - A chemical reaction in which the physical properties of a rubber are changed in the direction of decreased plastic flow, less surface tackiness, and increased tensile strength by reacting it with sulfur or other suitable agents.

Working Life - The period of time during which an adhesive, after mixing with catalyst, solvent, or other compounding ingredients, remains suitable for use.

Yield Value - The stress (either normal or shear) at which a marked increase in deformation occurs without an increase in load.

USE IN INDUSTRY

ANIMAL HIDE GLUE

1. FURNITURE MFG.
2. GUMMED PAPERS
3. MATCH INDUSTRY

CASEINS

1. PAPER & CLOTH SIZING
2. BOTTLE & CAN LABELS
3. CIGARETTE PAPER ADHESIVE

RESORCINOL RESINS

1. PLYWOOD ADHESIVE MARINE
2. LAMINATED STRUCTURES
3. PLASTIC BONDING

UREA RESIN

1. CHIP BOARD
2. EXTERIOR PLYWOOD
3. PAPER BAGS

EPOXY RESIN

1. HONEYCOMB STRUCTURES
2. AUTO BODY PATCHING COMPOUND
3. AIRCRAFT INDUSTRY

POLYVINYL RESIN

1. ENVELOPES
2. PENCILS
3. WALL PAINTS

CONTACT CEMENT

1. COUNTER & TABLE TOPS
2. PLYWOOD TO FLAT SURFACES
3. WALL CLIPS

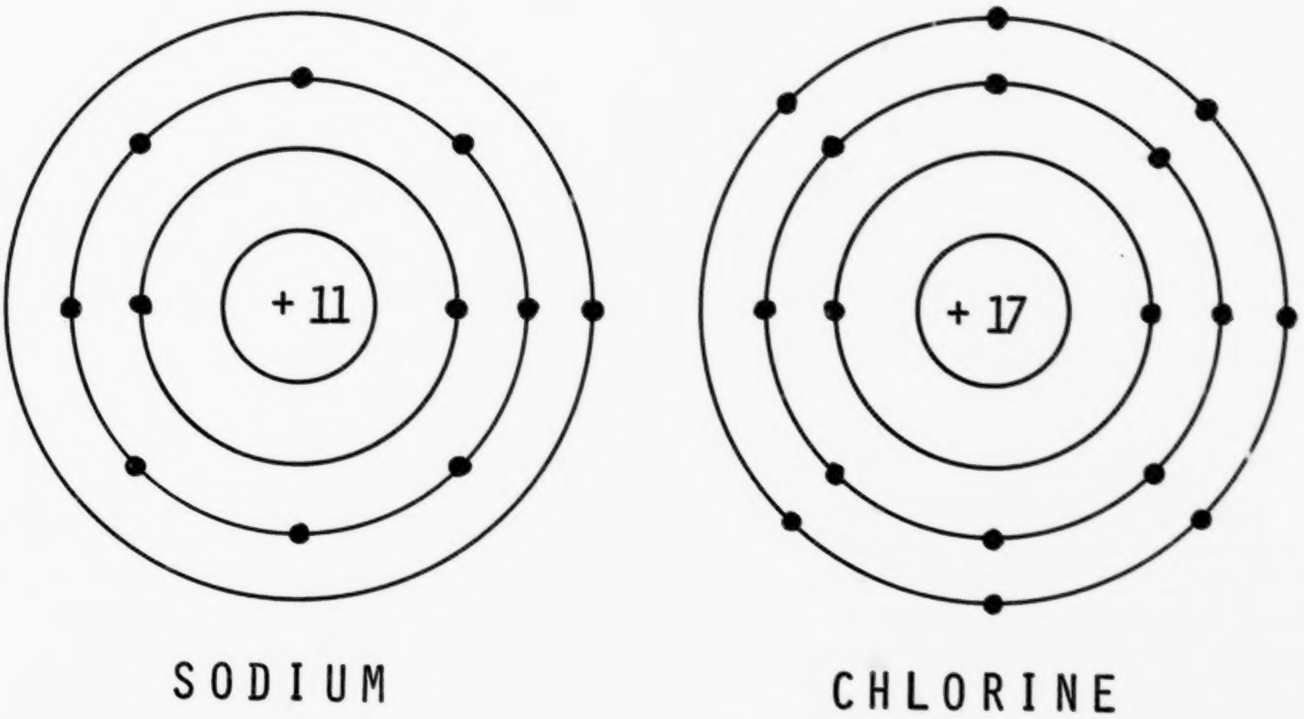
PLASTIC RESIN

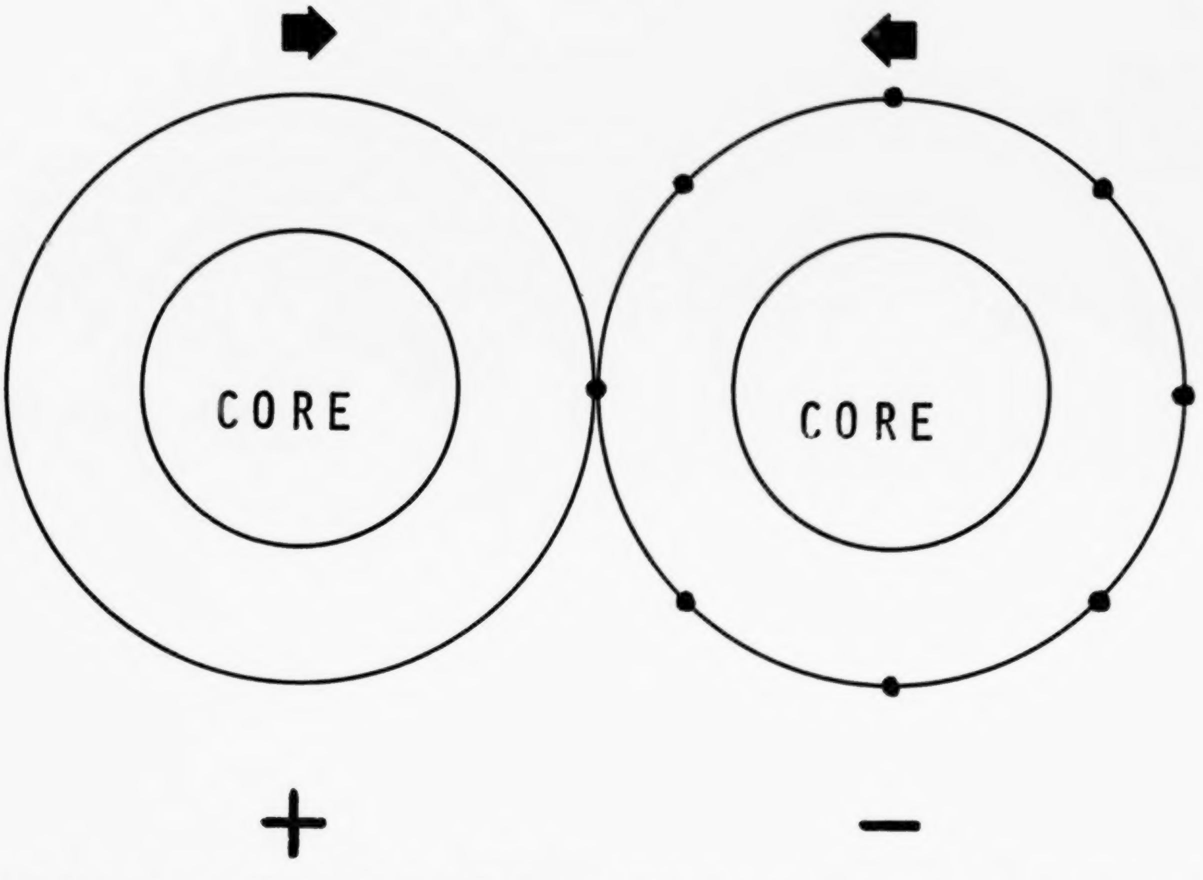
1. FURNITURE VENEER
2. PAPERMAKING
3. CABINETMAKING

ALIPHATIC RESIN

1. TEXTILE FINISHING
2. PAPERMAKING
3. LAMINATING

IONIC BONDING

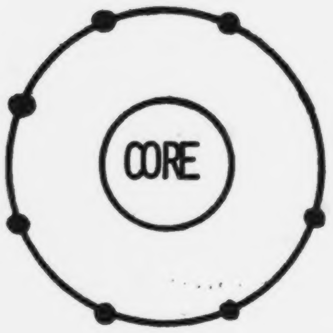

+11
+17
SODIUM
CHLORINE



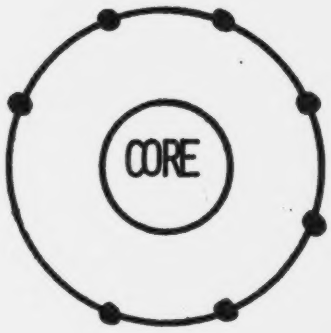
CHLORINE GRABS SINGLE ELECTRON TO ACHIEVE STABLE OCTET AND BECOMES NEGATIVE ION. SODIUM BECOMES POSITIVE ION. BOUND BY ELECTROSTATIC FORCES.

#10

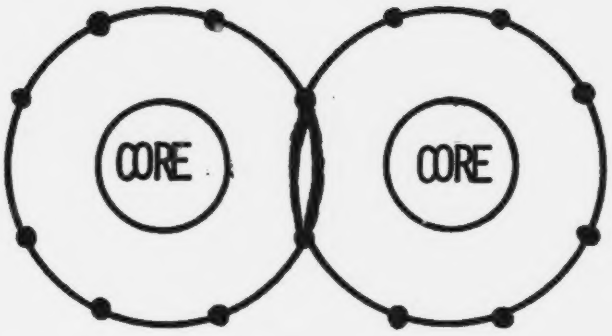
COVALENT BONDS



CHLORINE
7 ELECTRONS
IN VALENCE

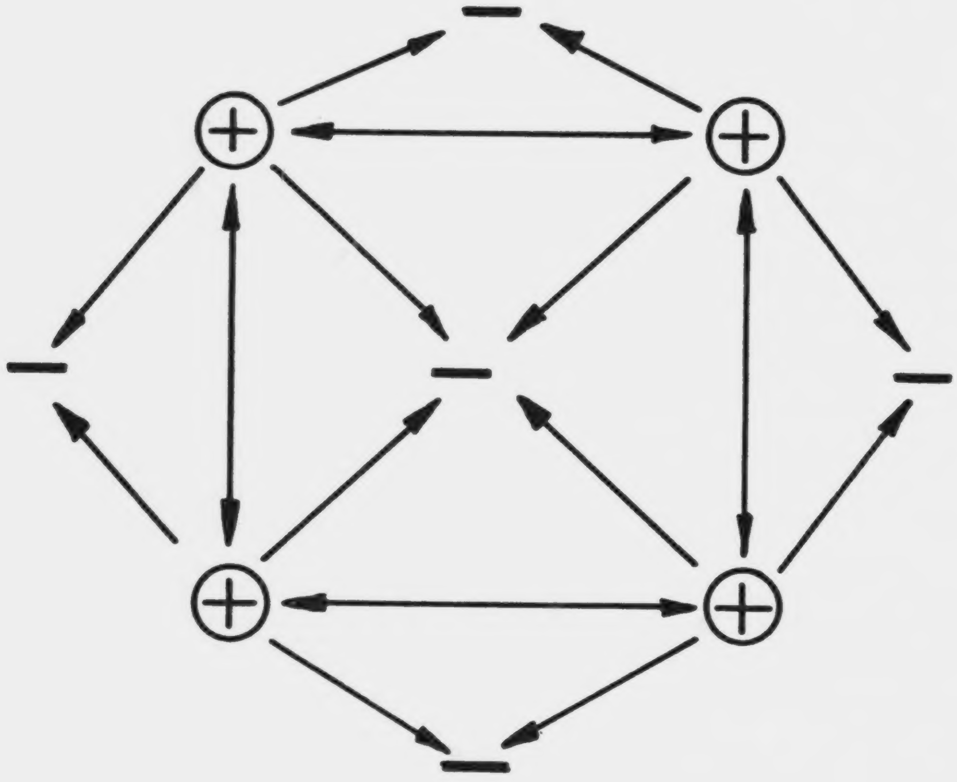


FLUORIDE
7 ELECTRONS
IN VALENCE



DOUBLE BOND: BY SHARING ONE ELECTRON EACH, BOTH ATOMS REACH STABLE OCTET AND WILL NOT BREAK BONDS EASILY.

METALLIC BOND



— ELECTRON

⊕ ATOM WITHOUT VALENCE

→ ATTRACTION FORCE

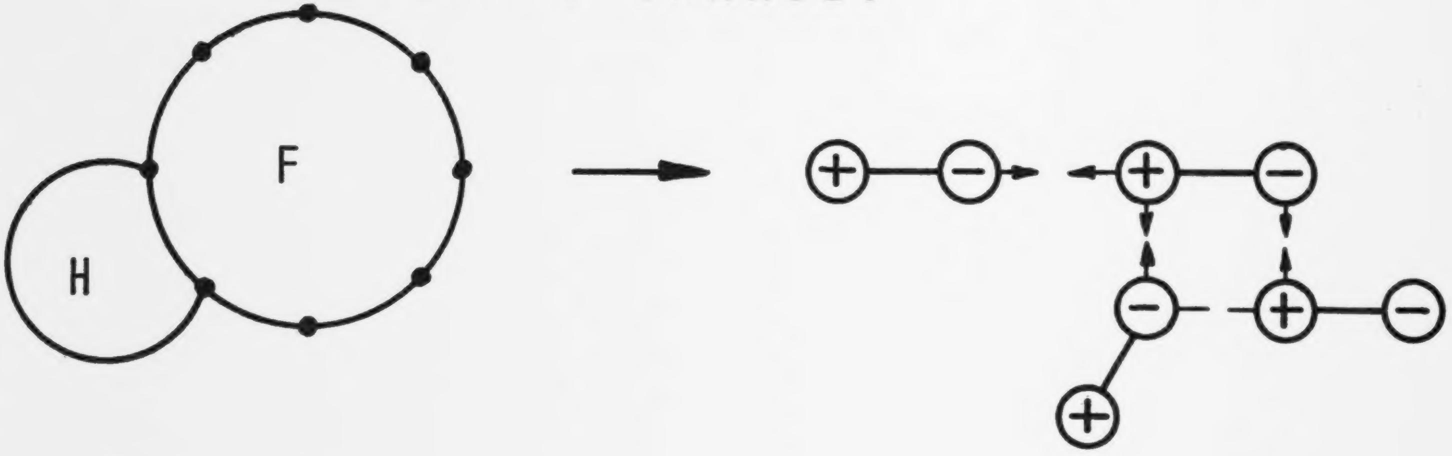
↔ REPULSION FORCE

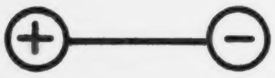
IRON

EACH ATOM HAS 2 VALENCE ELECTRONS. ELECTRONS FORM A CLOUD WHICH IS NEGATIVE. THESE ATTRACT POSITIVE CHARGES. POSITIVE IONS OR CORES ARE SURROUNDED BY FREE VALENCE ELECTRONS.

VAN DER WAALS FORCES OF MOLECULES

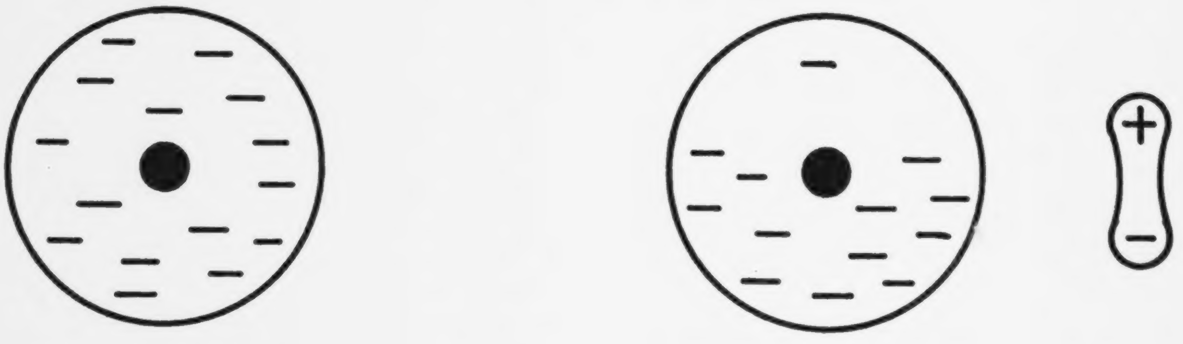
ELECTRIC CHARGES





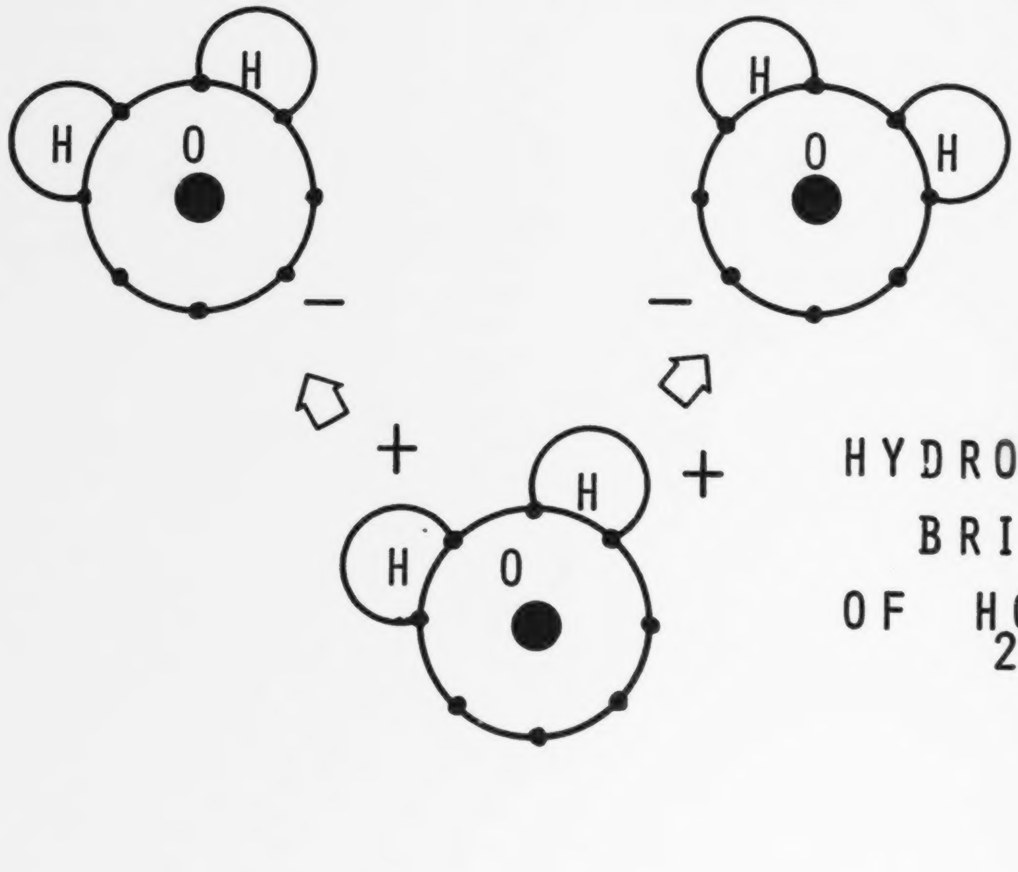
"DIPOLE"

DISPERSION EFFECTS



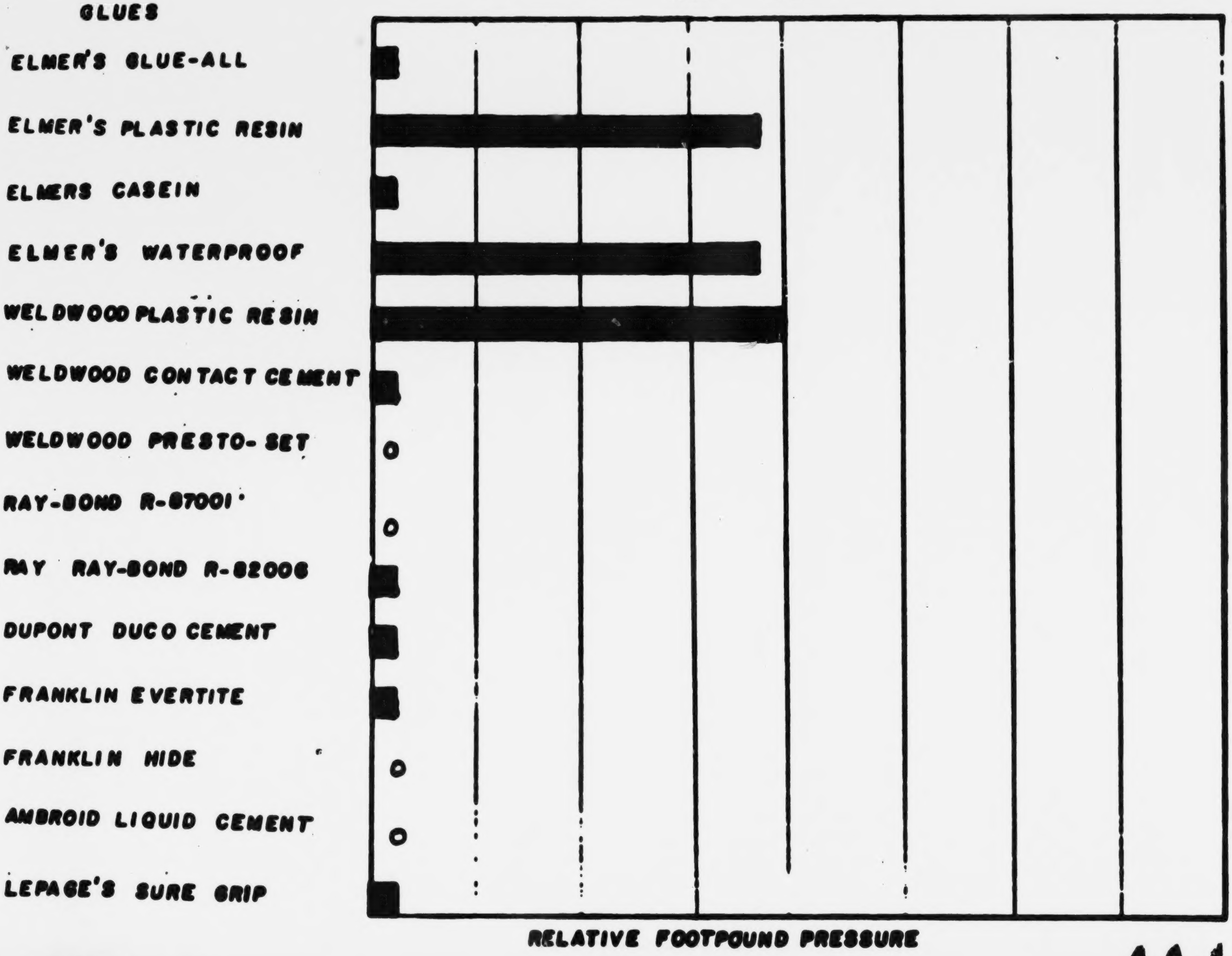
UNIFORM
(CHARGE BALANCED)

POLARIZED
(CHARGE UNBALANCED)

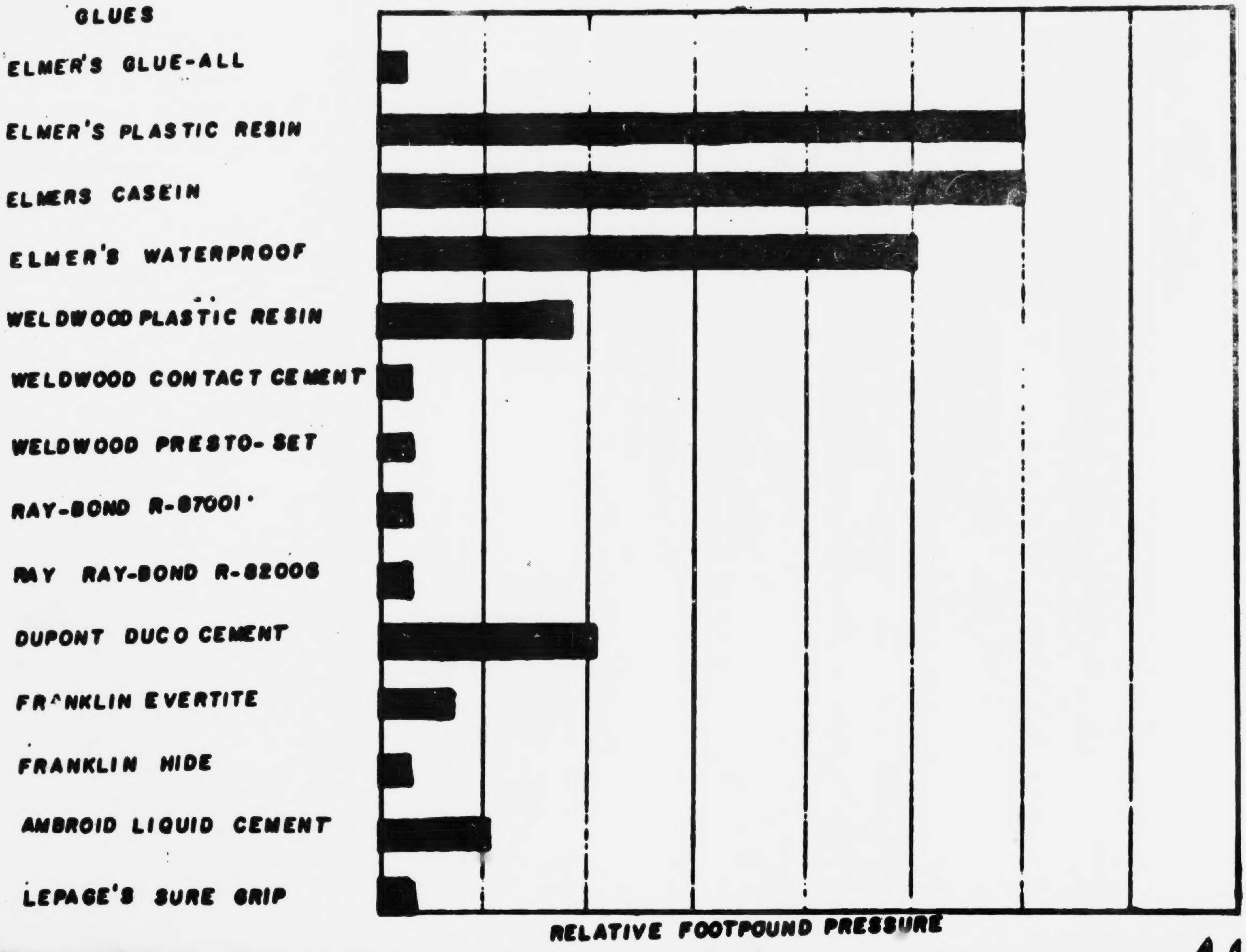


HYDROGEN
BRIDGE
OF H_2O

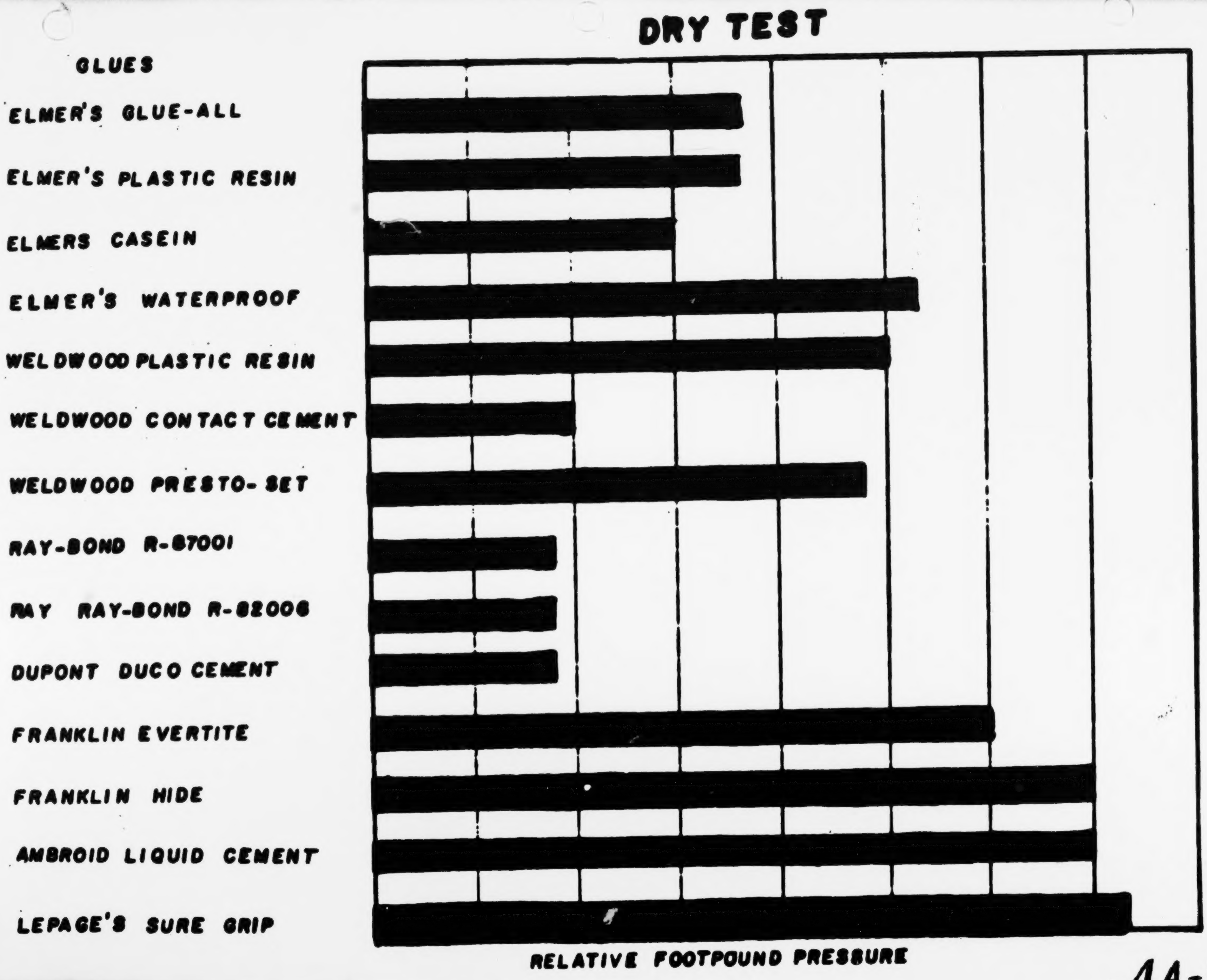
WET TEST


GLUES
ELMER'S GLUE-ALL
ELMER'S PLASTIC RESIN
ELMERS CASEIN
ELMER'S WATERPROOF
WELDWOOD PLASTIC RESIN
WELDWOOD CONTACT CEMENT
WELDWOOD PRESTO-SET
0
RAY-BOND R-87001
0
RAY RAY-BOND R-82006
DUPONT DUCO CEMENT
FRANKLIN EVERTITE
FRANKLIN HIDE
0
AMBROID LIQUID CEMENT
0
LEPAGE'S SURE GRIP
RELATIVE FOOTPOUND PRESSURE

HEAT TEST



4A-2


DRY TEST
GLUES
ELMER'S GLUE-ALL
ELMER'S PLASTIC RESIN
ELMERS CASEIN
ELMER'S WATERPROOF
WELDWOOD PLASTIC RESIN
WELDWOOD CONTACT CEMENT
WELDWOOD PRESTO-SET
RAY-BOND R-87001
RAY RAY-BOND R-82006
DUPONT DUCO CEMENT
FRANKLIN EVERTITE
FRANKLIN HIDE
AMBROID LIQUID CEMENT
LEPAGE'S SURE GRIP
RELATIVE FOOTPOUND PRESSURE

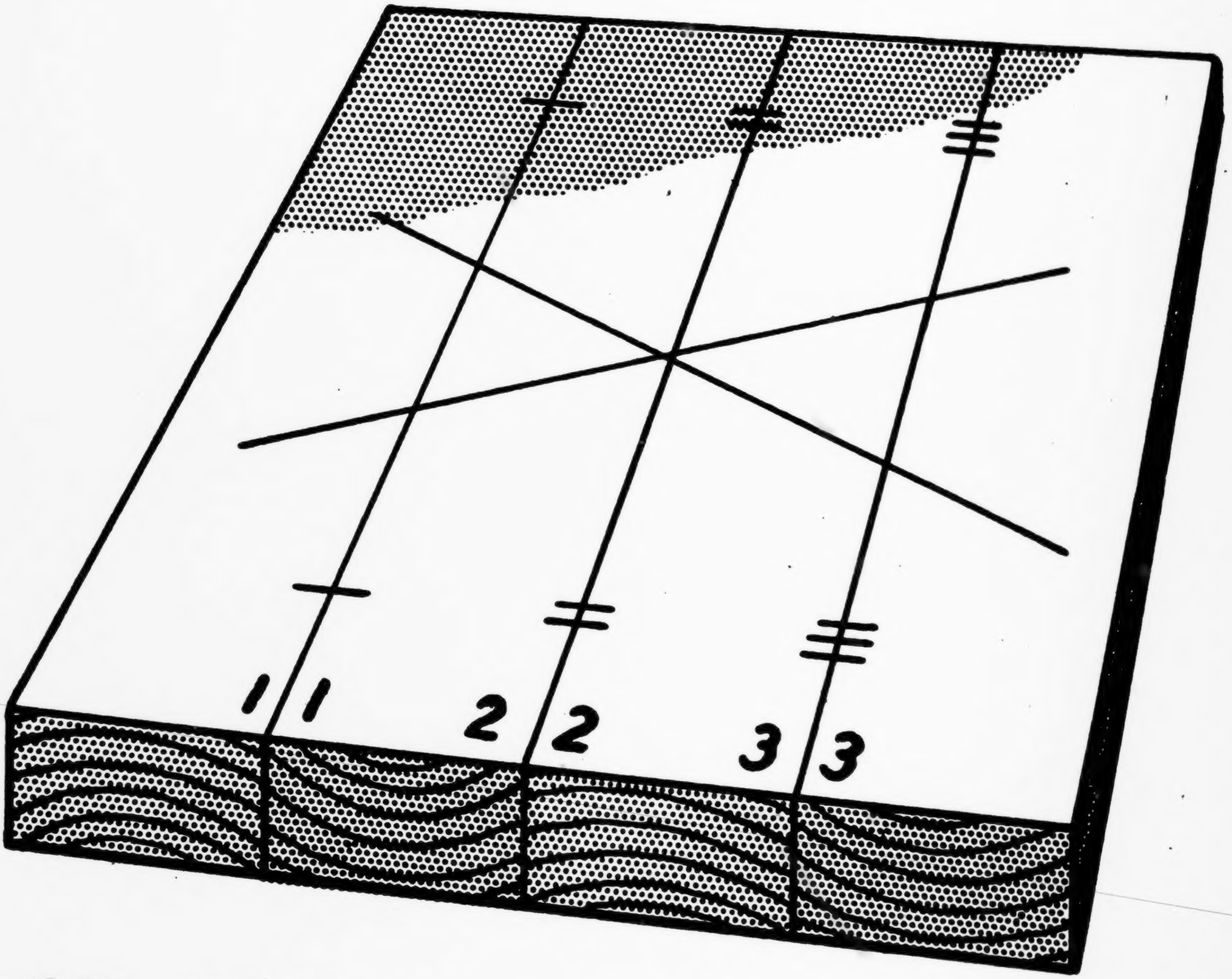
4A-3

40-3.—CHART OF COMMON ADHESIVES

Kind	Animal (Liquid Hide) Glue	Powdered Casein	Polyvinyl White Liquid Resin Glue	Plastic Powdered Resin
CHARACTERISTICS				
Especially good for:	First choice for furniture work and wherever a tough, lasting wood-to-wood bond is needed. A favorite for cabinetwork and general wood gluing.	Will do most woodworking jobs and is especially desirable with oily woods: teak, lemon, yew.	A fine all-around household glue for mending and furniture making and repair. Excellent for model work, paper, leather, and small assemblies.	Use it for woodworking and general gluing where considerable moisture resistance is wanted.
Disadvantages:	Because it is not waterproof, do not use it for outdoor furniture or for boat building.	Not moisture resistant enough for outdoor furniture. Will stain acid woods such as redwood. Must be mixed for each use.	Not sufficiently moisture-resistant for exposure to weather. Not so strong and lasting as liquid hide glue for fine furniture work. Softens under heat and solvents.	Do not use with oily woods or with joints that are not closely fitted and tightly clamped. Must be mixed for each use.
Advantages:	Very strong because it is rawhide-tough and does not become brittle. It is easy to use, light in color, resists heat and mold. It has good filling qualities, so gives strength even in poorly fitted joints.	Strong, fairly water-resistant, works in cool locations, fills poor joints well.	Always ready to use at any temperature. Nonstaining, clean and white. Quick-setting qualities recommend it for work where good clamping is not possible.	Very strong, although brittle if joint fits poorly. Light-colored, almost waterproof.
Source:	From animal hides and bones.	From milk curd.	From chemicals.	From chemicals.
USE				
Room Temperature	Sets best above 70°. Can be used in colder room if glue is warmer.	Any temperature above freezing. But the warmer the better.	Any temperature above 60°. But the warmer the better.	Must be 70° or warmer. Will set faster at 90°.
Preparation	Ready to use.	Stir together equal parts by volume glue and water. Wait 10 minutes and stir again.	Ready to use.	Mix 2 parts powder with 1/2 to 1 part water.
Apply	Apply thin coat on both surfaces; let get tacky before joining.	Apply thin coat to both surfaces. Use within 8 hours after mixing.	Spread on and clamp at once.	Apply thin coat to both surfaces. Use within 4 hours after mixing.
70° Clamping Time	Hardwood: 2 hrs.	2 hrs.	1 hr.	16 hrs.
	Softwood: 3 hrs.	3 hrs.	1½ hrs.	[illegible]

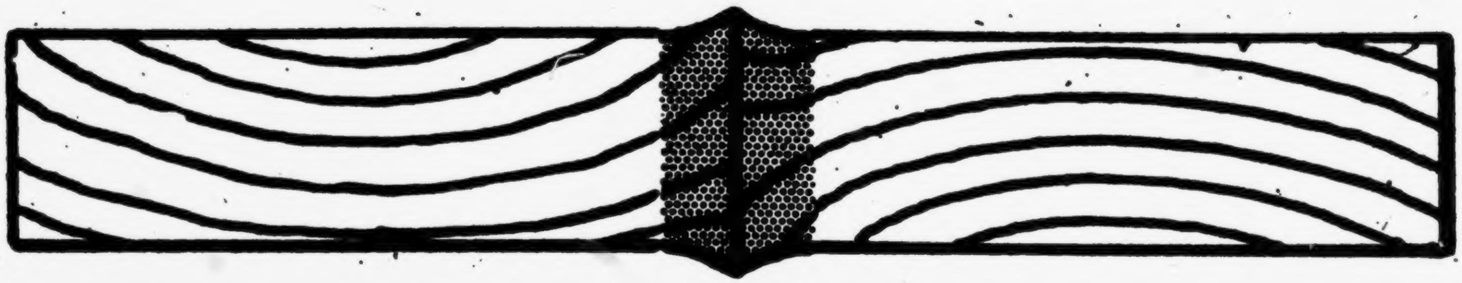
40-3.—CHART OF COMMON ADHESIVES (Continued)

Aliphatic Resin	Resorcinol	Contact Cement	Epoxy Cement	Urea Resin
CHARACTERISTICS				
Good for furniture and case goods assembly. Also edge and face gluing. Same as polyvinyl but with better results.	This is the glue for any work that may be exposed to soaking: outdoor furniture, boats, wooden sinks.	For bonding veneer, plastic laminates, leather, plastic, or canvas to wood.	Will bond wood to metal or other dissimilar materials. Use in combination with wood, tile, metal, glass, etc. Will not shrink or swell during hardening. Waterproof, oil proof, and non-inflammable.	Edge gluing with high frequency and steam heated pressing. Interior and limited exterior use.
Lacks moisture resistance. Tends towards separation of glue and thinner during storage.	Not good for work that must be done at temperatures below 70°. Because of dark color and mixing, not often used unless water-proof quality is needed.	Parts can't be shifted once contact is made. Dangerous without proper ventilation.	Not good for fastening wood to wood in large products. (Must be used in well-ventilated room. Avoid getting into eyes.)	Poor gap-filling properties. Limited pot life. Requires careful mixing and handling. Moisture content of wood must be from 7 to 10 per cent.
Compared to polyvinyl it resists heat better, sands better, spreads easier, and is less affected by lacquers. Not easily rubbed off.	Very strong, as well as waterproof. It works better with poor joints than many glues do.	Adheres immediately on contact. No clamping. Test for dryness by pressing wrapping paper to surface. If paper doesn't stick, surfaces are dry and ready for bonding.	Can be painted, sanded, filled, drilled, or machined. Can fill large holes.	Highly moisture resistant. Ideal for high frequency bonding. Dries white or nearly colorless.
From chemicals.	From chemicals.	Synthetic rubber (neoprene, nitrile, or polysulfide).	From chemicals.	From chemicals. A thermosetting resin.
USE				
Any temperature above 45°.	Must be 70° or warmer. Will set faster at 90°.	70° or warmer.	Any temperature.	70° or warmer.
Stir before using. Ready for use.	Mix 3 parts powder to 4 parts liquid catalyst.	Ready to use.	Resin and hardener mixed in amounts stated on container.	Resin and catalyst must be carefully mixed.
Spread on and clamp.	Apply thin coat to both surfaces. Use within 8 hours after mixing.	Brush on liberal coat. Dry for 30 minutes. Apply second coat.	Apply with stick or brush.	Apply with roller.
1 hr.	16 hrs.	No clamping. Bonds instantly.	No clamping. Drys faster with heat.	A few seconds with high frequency heat.
1½ hrs.	16 hrs.			

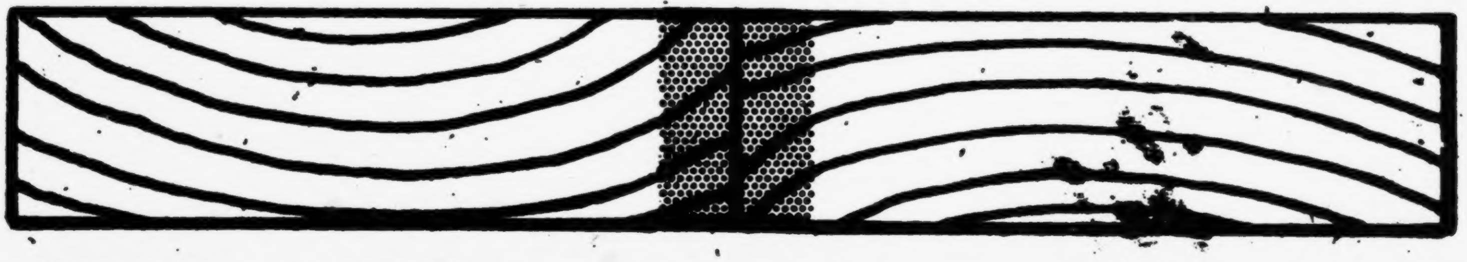


40-25. Note the correct arrangement of the pieces before gluing up. The large "X" and other markings will make assembly easy.

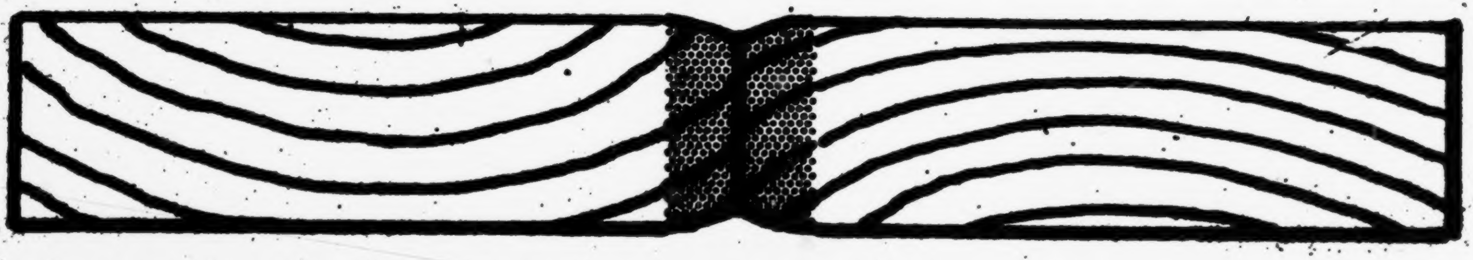
40-22. This is what will happen if a glued-up panel is surfaced while there is a raised glue line.



JOINT EXPANDED BY MOISTURE IN GLUE.

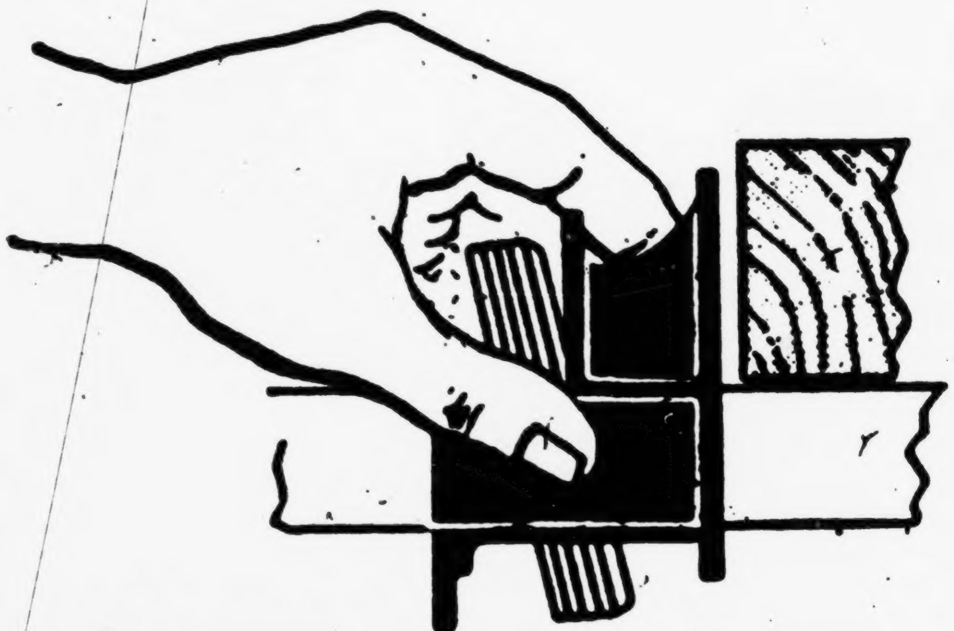


WOOD SURFACED BEFORE WOOD IS DRY.



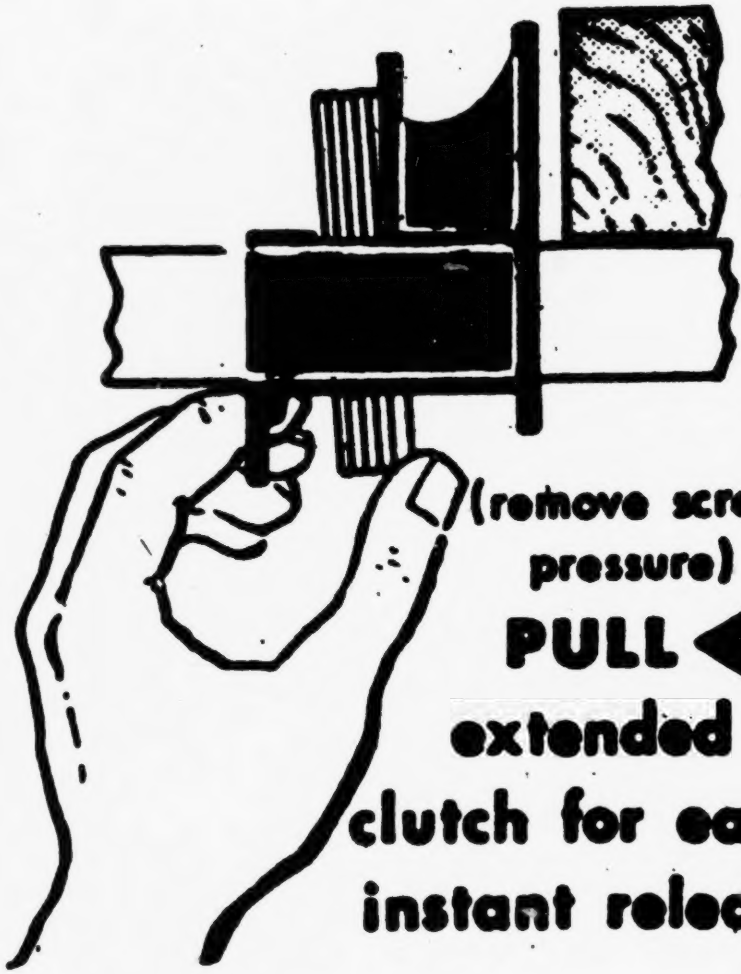
SUNKEN WOOD JOINT WHEN DRY.

40-9(b). The friction clutch can be moved in or out into any clamping position. The screw pressure must be removed before the clutch will move.



→ **PUSH** to zip tail-stop against work

(apply final screw pressure)

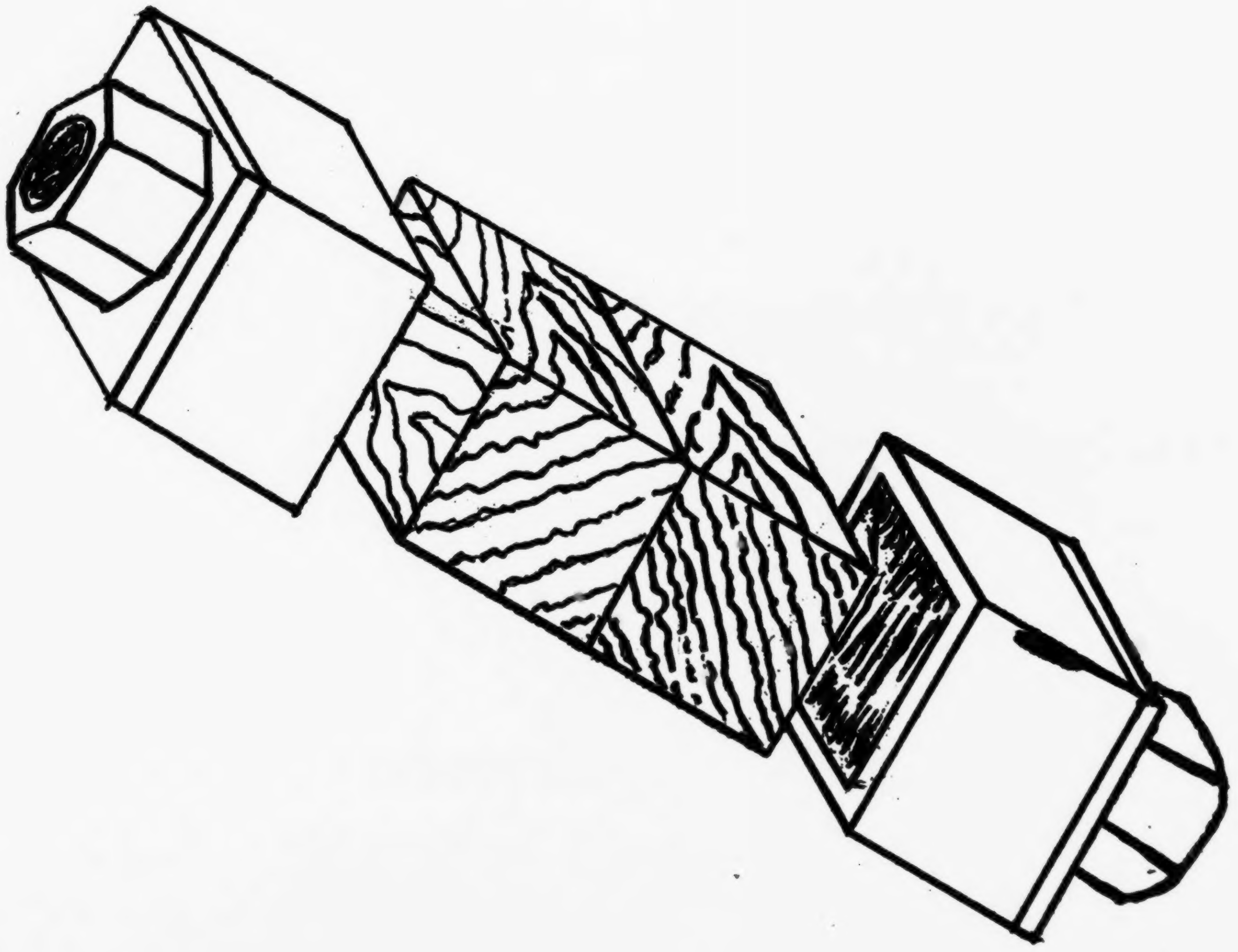


(remove screw pressure)

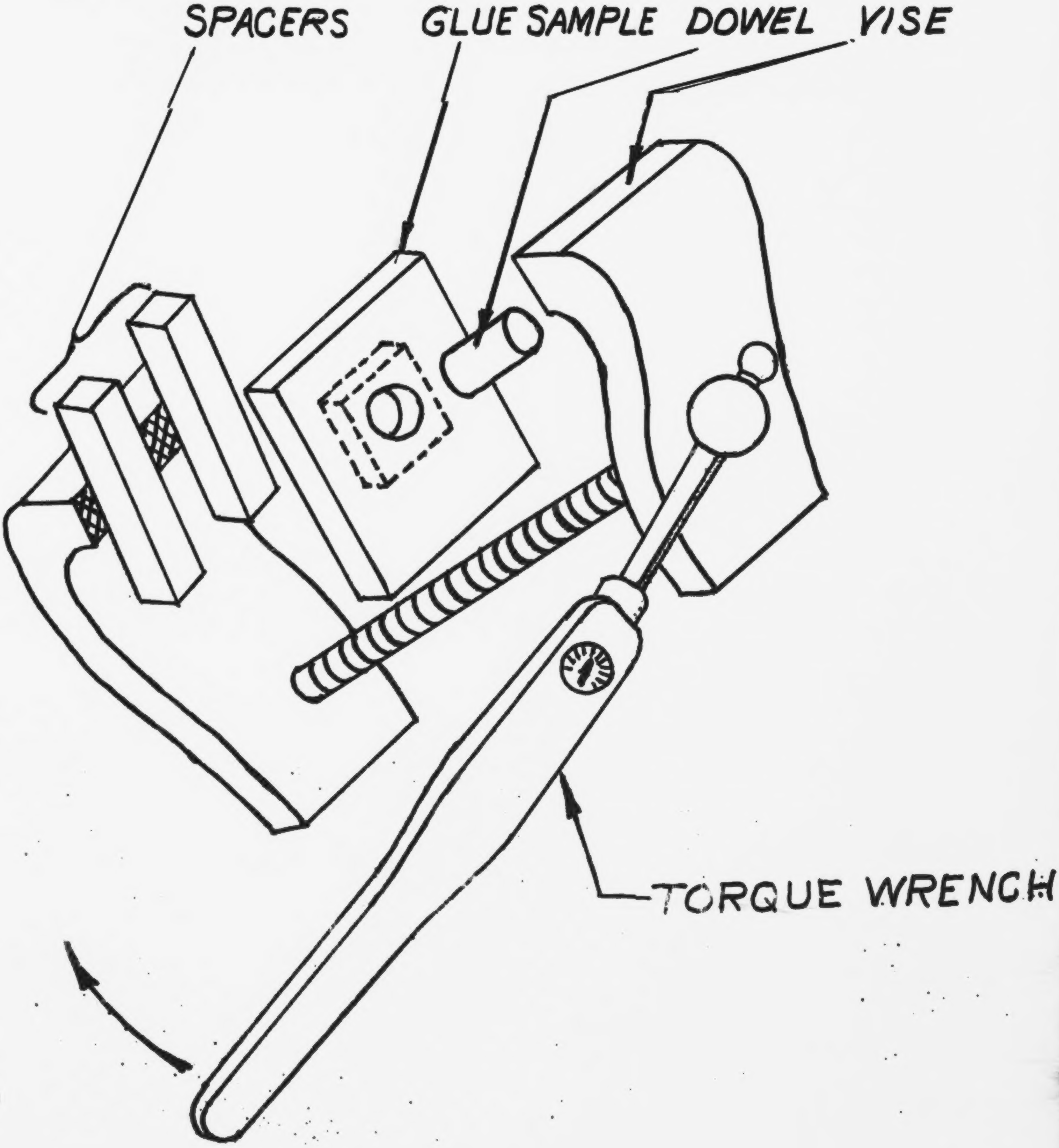
PULL ← extended clutch for easy instant release

SHEAR TEST EQUIPMENT

USE WITH TORQUE WRENCH



TENSIL TEST EQUIPMENT


SPACERS
GLUE SAMPLE
DOWEL
VISE
TORQUE WRENCH

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Thayne McKnight
Grant Junior High
Denver, Colorado

Jim Peters
Caroline Davis Junior High
San Jose, California

INSTRUCTIONAL LEVEL: Junior High School

TITLE: An Analysis of Wood as a Material

PRESENTATION TIME: 1 hour

INTRODUCTION:

We all admire a beautiful piece of furniture. To appreciate quality, however, we must go back to the sources of our fine woods. To be effective in processing these woods, it is of utmost importance to be familiar with the structure of a tree. More specifically, we are compelled to study and present the composition of the individual cell if we are to understand the physical properties and working characteristics of wood.

OBJECTIVES:

To introduce wood as a material
To view wood in its natural environment (the forest)
To become familiar with the structure of a tree
To study the composition of the individual cell
  a. Atomically
  b. Chemically
To understand the important affinity of water to the cellulose molecule
To know the various classifications and characteristics of wood

INTER-RELATION WITH OTHER SUBJECTS;

UNIT SUBJECT AREA: Wood

INTER-RELATION WITH OTHER SUBJECTS;

Graphic arts and drawing - A knowledge of wood as a material is important in the production of products for these areas.

Science - Through a discussion of the atomic structure of a cell and a break down of its chemical components.

USE IN INDUSTRY:

Wood is one of man's most abundant materials and is one of the easiest materials to work with. With the advent of new synthetics and processes, wood is being utilized in many different ways. Wood must be understood on a molecular level to stay abreast of new applications in this everchanging technological world.

MATERIALS AND EQUIPMENT:
Compressed wood pellets
Glass beaker
Water

Instructions:
Compress wood shavings into some form (pellets most desirable)
The compression must be tight and compact
Do not use any type of adhesive to hold the shavings together
Put the compressed shavings in a glass beaker and slowly add water.
The sawdust or shavings will grow to illustrate the tremendous affinity that the cellulose molecule has for water.
A pressure device and scale may be rigged to show the great amount of energy released during the absorption.

EDUCATIONAL MEDIA:
Slide series (Included with this unit)
Slide projector

UTILIZATION IN THE TEACHING LEARNING ENVIRONMENT:

SAFETY:
No special safety rules involved.

PRESENTATION:

- I. Forests
  - A. Home of wood
  - B. Organic Material
    - 1. All organic materials contain carbon
    - 2. Composed of cellulose, water, and lignin
  - C. Nature manufactures wood
    - 1. No real control over final product
    - 2. Geographical regions, soil, and climate play a part in development.
- II. Structure of a tree
  - A. Basic parts
    - 1. Root system
      - a. Sends food up the tree
      - b. Supports the tree
      - c. Only a small portion is alive...most of the structure is dead woody material

2. Trunk
    a. Contains bulk of tree area
    b. Only a small part around the outside of the tree trunk is alive (cambium)
3. Branches
4. Leaves
    a. Manufactures food through photosynthesis
    b. Sends food supply down to the branches, trunk, and roots.

B. Parts of the trunk and their functions
1. Pith
    a. Porous center material
    b. Sometimes rots and dies leaving a hollow center
2. Heartwood
    a. Darker in color
    b. "Garbage dump" for resins
        (1) Waste products of a tree
    c. Resins create a built-in protector from insects
        (1) Maple is an exception
    d. Older wood
    e. It is dead for all practical purposes
    f. More desirable for furniture construction
3. Sapwood
    a. Lighter in color
    b. Newer, outer growth
    c. Carries food supply up the tree
4. Cambium
    a. Pitchlike material
    b. The only "living" part of the trunk
    c. Cell producing area for new wood
        (1) Produces new sapwood on one side and new bark on the other
5. Phloem
    a. Inner bark
    b. Carries food from the leaves to the branches, trunk, and the root system
6. Outer bark
    a. Dead, corky covering
    b. Varies in appearance and thickness with each type of tree
    c. Protects the tree

7. Annual rings
    a. Growth pattern for one year (approximate)
    b. The summer growth of denser cellular growth

8. Medullary rays
    a. Radial pattern from center of tree to the bark
    b. Forms cross feeding passageways
9. Spring Growth
    a. More moisture
    b. Tree develops more rapidly
    c. Large tubes with thin walls

10. Summer growth
    a. Less moisture
    b. Tree develops slower
    c. Small cells with thick walls
    d. Creates a denser area

III. Nature of wood
  A. Individual cells
    1. Basic structure of cellulose molecules that form long tubular cells.
      a. Fine as human hair
      b. Walls of cell are finer strands of cellulose
      c. Food passageway up the tree
      d. Carbohydrates...composed of hydrogen, carbon, and oxygen
    2. Cells are held together with lignin
      a. Natural bonding agent
      b. Exact composition is unknown
  B. Mineral matter in wood
    1. Magnesium, potassium, iron, and aluminum
  C. Other elements found in wood
    1. Resins and oils
  D. Tremendous affinity for water
    1. Moisture in wood will equal moisture in air
      a. Shrinkage or expansion is the result of an imbalance
      b. Humidity differs in each geographical part of the country
        (1) 7% in Arizona - 12% in San Francisco area

IV. Moisture content of green wood
  A. 30 - 300% moisture content by weight
    1. Water in cells is called "free water"
      a. There will only be free water after the walls of the cells are saturated
    2. Water in cell walls
  B. Drying
    1. Free water in cells is removed first
      a. No shrinkage at this point
      b. 23-30% moisture content
      c. Wood is at fiber-saturation point

        2. Water in cell walls is then removed
            a. Shrinkage occurs
            b. 6-10% moisture content desirable for furniture construction
            c. Wood will expand or contract in home
                (1) Due to the temperature and moisture content in the home
                (2) Warpage and cracks may occur
        3. Denser areas will absorb more water
            a. Annual rings (summer growth) are denser areas and will contract and expand more than the spring growth
            b. If the density of the wood was uniform throughout, there would be relatively no warpage or deformation of the wood

V. Classification of wood
    A. Hardwood
        1. Deciduous trees
            a. Leaves drop in the autumn
            b. Cellular structure denser
                (1) Small cells with thick walls
    B. Softwood
        1. Coniferous (cone bearing)
            a. Evergreen
            b. Cellular structure less dense
                (1) Large cells with thin walls
    C. Open grain wood
        1. Looser bonding of cells to each other
    D. Close grain wood
        1. Tighter bonding of cells to each other

VI. Characteristics of wood
    A. Wood is distinguished by many different characteristics
        1. Color
        2. Smell
        3. Hardness
        4. Grain patterns
        5. Texture
        6. Workability
        7. Strength
        8. Holding power

VII. Review
    A. Wood is an organic material produced by nature
    B. Basic parts of the tree are:
        1. Root system
        2. Trunk
        3. Branches
        4. Leaves
            a. Each have specific parts and functions that are interrelated toward the efficient growth of the tree

C. Basic structure is the cellulose molecule
    1. Hydrogen, oxygen, and carbon

D. Water is the most important single factor in the development and usability of the tree

E. Several classifications and characteristics of wood

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Involve students during presentation to stimulate interest. Testing of students on unit material will be developed by individual teachers to suit their needs.

UNIT EVALUATION:

By student testing (include adequate sampling of each topic area).

By noting student response during lecture and demonstration.

Slides may be added or subtracted to further enhance unit success for each individual instructor.

DEFINITION OF TERMS:

1. Cell - Small tubular shaped cavities forming the basic structure of a tree
2. Cellulose - A carbohydrate forming the solid framework (cell walls) of plants
3. Lignin - A substance related to cellulose. The natural bonding agent for cellular structures of trees
4. Pith - The loose spongy tissue occupying the center of the trunk
5. Heartwood - The hard central part of the trunk
6. Sapwood - The lighter, more porous, and younger wood, beneath the bark and extending to the heartwood of the tree
7. Cambium - The soft formative tissue which gives rise to new tissues in the trunk of the tree
8. Phloem - A complex tissue which consists of sieve tubes serving for conduction of food materials
9. Medullary rays - Radial plates usually separating the vascular bundles
10. Annual rings - Caused by summer growth and marking the growth for a year
11. Molecule - The smallest portion of an element or compound that retains chemical identity with the substance in mass
12. Photosynthesis - Formation of carbohydrates in the chlorophyll--containing tissues of plants exposed to light

13. Carbohydrate - Any of a group of neutral compounds composed of carbon, hydrogen, and oxygen, and including the sugars, starches, etc.

REFERENCES:

STUDENT:

Student woodworking textbook
Basic physical science textbook

TEACHER:

1. Feirer, John. Industrial Arts Woodworking. Bennet Co., Inc., 1965, pp. 327-352.
2. Farb, Peter. The Forest. Time Inc., 1963.
3. Brown, Panshin, and Forsaith. Textbook of Wood Technology. McGraw-Hill, Vol. I, 1949.
4. U.S. Department of Agriculture. Wood Handbook. U.S. Government Printing Office, Number 72, 1955.
5. ASTM Standards. American Society for Testing and Materials, Part 16, June 1967.

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Stanley Marich
Santa Clara Unified School District
Jefferson Intermediate School
Santa Clara, California

INSTRUCTIONAL LEVEL: Intermediate or Junior High School

TITLE: Forest By-Products

PRESENTATION TIME: 8 class periods

INTROCUTION:

Forests provide raw materials for five major manufacturing industries and full time employment for more than one million, five-hundred-thousand persons. Forest industries provide twenty billion dollars worth of the nation's gross national product.

Through a better understanding of the raw material, the woods industry is continually developing many new products for society's use. The student should be informed of the "why" of woods as well as the "how" with woods.

OBJECTIVES:

To narrow the gap of understanding between raw materials of industry and the finished product in terms of forest by-products.

To acquaint the student with some of the problems faced by producers of consumer goods in the selection of raw materials.

To show how scientific knowledge and the use of modern methods aid in the conservation of our forests, and to recognize the fact that scientific research is responsible in large part for the development of great industires.

To demonstrate that much can be learned by use of simple tests, equipment and demonstrations.

To provide opportunities for students to experiment; to do research on forest products; to observe demonstrations too expensive, dangerous or time consuming for them to perform.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Woods

INTER-RELATION WITH OTHER SUBJECTS:
Social Studies, Arithmetic, Science, English, Reading

USE IN INDUSTRY:

The by-products of forests are used to make over 5,159 products. Examples of some of the uses are: paper, insulation board, cord-rope, onion skin, lacquers, explosives, acetic acid, acetone, charcoal, bakery yeast, turfurural, sugars, alcohol, resins, turpentines, creosote, etc.

MATERIALS AND EQUIPMENT:

Normal equipment found in industrial arts area

Samples of raw materials of the forest: trunk, limbs, etc.

Samples of extractives: turpentine, alcohol, acetic acid, wax, aceton, etc.

Samples of paper, paper board, particle board, plastics (from wood cellulose)

Basic science equipment: test tubes, tubing, burners, ring stands, clamps, etc.

Microscope, bioscope or microprojector -- Bioscope highly recommedned -- many of the dmonstrations in this unit are designed for projection with the bioscope. The whole field of cellulose fiber study is much more easily understood by projection of various fibers in group situations. A microscope will also accomplish the same purpose. The time factor should be a consideration.

Paper-making kit

Simple distillation apparatus - omit condenser and substitute 3/8" tubing with a right-angle bend.

Overhead projector

Film projector

Flat iron (for heat in paper-making)

Source of heat - bunsen burner, propane torch, etc.

EDUCATIONAL MEDIA:

Set of 13 offset prints illustrating the major concepts in this unit.

Displays of some of the samples mentioned under "Materials and Equipment"

Wall display "Products of the Tree Farm" - American Forest Products Industries, Inc.

"The Story of Pulp and Paper" - American Forest Products Industries, Inc. (A step by step account of paper-making process)

"The Story of Lumber and Allied Products" - American Forest Products Industries, Inc. (Special attention is given to many recent developments in finding new uses for wood leftovers.)

Film - "From Trees to Paper" - American Forest Products Industries Inc.

Wood Handbook, No. 72, U.S. Dept. of Agriculture

People and Timber (tells the story of our timber situation and takes a look into the future) Misc. Publication, No. 721. Superintendent of Documents, U.S. Gov't Printing Office.

Film - "It's a Tree Country" - American Forest Products Industries, Inc.

Film - "From Trees to Lumber," - American Forest Products Industries, Inc.

UTILIZATION IN THE TEACHING-LEARINING ENVIRONMENT:

SAFETY:

1. Students should be cautioned and closely supervised in the use of any caustic substances such as strong acids, bases, etc.
2. Students need close supervision in the use of testing equipment in order to avoid injury to themselves and others. Costly equipment is sometimes easily damaged; however, this should not deter the instructor from demonstrating or the students from using equipment whenever possible. With proper instruction and close supervision, this problem should not become serious.

PRESENTATION:

This unit has been developed around three sub-units: Pulpwood, Extractives and Structure of Wood. Any of the sub-units lend themselves for use, individually, or in combination. It is suggested that the teacher attempt to dovetail this unit into existing programs in industrial arts rather than treat as an isolated unit of study. It is the writer's opinion that too many industrial arts teachers spend too little time presenting forest by-products, yet, they represent nearly fifty per-cent of the harvest of the forests.

I. Forest Products (Trans. 1)
   A. What are forest products?
      Definition: Any material which is either grown or made from fiberous material located in the forest (give example - display samples of forest products) discuss.
   B. What are by-products?
      Definition - Exact definition is difficult to give. If major operation is pulpwood, then lumber would be a by-product.

II. Pulpwood (Trans. 2)
   A. What is Pulpwood?
      Definition: Timber used in making wood pulp (called woodpulp)

B. What is Woodpulp?
   Definition: Wood or timber used in making pulp. Wood reduced to pulp for making paper. Represents 10% of timber removed from forests yearly.

C. What is Pulp?
   Definition: The raw material for making paper and paper products.

D. Methods of making pulp
   1. Mechanical - pulp made by rubbing of pulpwood against an abrasive surface. This can be demonstrated by rubbing the vertical grain surface of a piece of wood on a piece of coarse stone or sandpaper. Put at right angles to the vertical grain to duplicate action of industrial method of "mechanical pulping." Place the "rubbings" in a small glass beaker and add water. Place a few drops of the mixture on a glass slide and project on a screen with the bioscope.
      Point out wood fibers to students. Notice that many of the fibers are damaged. Notice also the coarse structure of the pulp due to coarse method of obtaining. (This is important as it is one of the major differences between mechanical pulp and chemical pulp and determines the use to which the pulp can be put.) The other major difference is that the insoluble materials are not removed in mechanical pulping, whereas in chemical pulping, they may be removed. Relate to industry by projecting transparency of mechanical pulping and explaining the process. (Trans. 3)
   2. Uses of mechanical pulp.
      a. Newsprint
      b. Insulating Boards - Hardboards
   3. Mainly coniferous woods used

Activity: Students prepare mechanical pulp as in 1, filter with fine mesh screen, air or force dry, mix with white glue and compress. Similar to newsprint if fibers are finely ground.

E. Chemical Pulp
   Definition: Cellulose pulp prepared in digestors by chemical action
   1. Difficult to prepare. A good substitute for preparation is to tear up tissue paper and soak in water. Mix with mixer. Need about one pint of mixture, 5% tissue, 95% water.
   2. Place a few drops of mixture on a slide and project

with bioscope on screen (could use microscope). Point out wood fibers. Compare with slide of mechanical pulp prepared previously. Students should be lead to conclude that due to the smooth unbroken fiber structure of chemical pulp and due to the removal of more of the soluble and insoluble materials in chemical pulp, it will produce smoother and more tightly bound cellulose products. Producers of paper products have gone to great lengths in research and development in order to provide the public with the best products possible. (Trans. 4)

3. Uses of Chemical Pulp
   a. Paper
      1) Many kinds
      2) Prepare some paper
      3) Explain paper-making process
      4) Mention - fillers, sizing, coatings
      5) (Trans. 5)
      6) Films - show samples
      7) Rayon - show samples with bioscope
      8) Plastics - show samples
      9) Lacquers - show samples
      10) Cellophane - show samples
      11) Fiberboards - show samples
      12) Explosive (from cellulose nitrate)

III. Extractives
   A. (Trans. 6)
   B. Chemists have learned that there are several different ways of extracting substances from wood.
      1. Steam Distillation
         Definition: Steam is introduced during distillation.
         a. (Trans. 7) Explain process
         b. Products produced from steam distillation and their uses:
            1) Essential Oils and Oleo - Resins
            2) Soaps
            3) Paints and varnishes
            4) Medicines
            5) Dyes
            6) Tannins for leather
         c. Different woods used for specific extracts
      2. Destructive Distillation (Trans 8)
         a. Definition: Wood is carbonized in absence of air to give charcoal and volatile products
         b. All kinds of wood used
         c. Explain industrial method of distillation.

d. Products derived from destructive distillation
1) Charcoal
2) Tar
3) Pine Oil
4) Methyl Alcohol
5) Turpentine
6) Acetic Acid

Activity: Set up simple distillation apparatus described under materials and equipment. Distill some wood in order to convey concept of destructive distillation of wood.

3. Acid Hydrolysis
Definition: Converting major wood substance to sugars by treatment with dilute acid.
a. Mainly coniferous woods used.
b. Project transparency 9. Explain.
c. Derivatives of acid hydrolysis:
1) Sugars
a) Ethyl Alcohol
b) Food for cattle
c) Yeast (for brewing ale)
2) Lignin Derivatives
a) Vanillin (for vanilla flavoring)
b) Adhesives
d. Extractives are not part of the structure of wood, but they do contribute to the wood such properties as color, odor, taste, etc.

IV. Structure of Wood
A. Definition: The ash-forming minerals, lignin and cellulose make up the wood structure. Due to their uniform structure, any one of these three components, when isolated, retains the microstructural pattern of the wood.
B. Show Trans. 10.
C. The ultimate chemical analysis of wood is approximately:

Carbon	50.0% by weight of dry wood
Oxygen	43.4% by weight of dry wood
Hydrogen	6.0% by weight of dry wood
Nitrogen	0.1% by weight of dry wood
Ash (largely silica)	0.5% by weight of dry wood

D. Divide into various chemical compounds
1. Carbohydrates of high molecular weight
2. Lignin
E. The carbohydrate portion may be broken down into simple substances by hydrolysis with concentrated acids, to give true cellulose and semi-cellulose. The lignin content ranges from 23% in deciduous woods to 39.5% in coniferous woods, and is largely concentrated in the

fibers. Miscellaneous materials include fats, waxes, tannin and certain coloring materials known collectively as extractives.

F. Show trans. 11
   1. Atoms - smallest parts of elements which can take place in a chemical reaction
   2. Molecules - atoms combine in fixed proportions to form compounds of which are the smallest parts capable of independent existence.
   3. Micelles - the in-between stage to forming a fibril. One micelle is 1/100,000 mm. in length.
   4. Fibrils - thread-like structures which become exposed during beating and give rise to the bonding properties of fibers in the paper.
   5. Fiber - a general term for a narrow, elongated cell with tapering ends.
   6. Plant - the final living structure

G. Show trans. 12.
   All living organisms are composed of individual cells, each of which is a self-contained unit. It is these adult cells or fibers in wood that give support to the tree. They are located between and around the vessels of the wood.
   1. Look at some fibers:
      a. Show some fibers of chemical pulp with bioscope.
      b. Show some fibers of mechanical pulp with bioscope.
   2. Fiber is composed of a hollow central canal or lumen, surrounded by four distinct fiber walls. Remember that it is the last layer, containing tough spiral windings of a water resistant nature, which during beating, and to a lesser extent during chemical pulping, becomes partially or completely removed. This exposes the underlying layers to the action of water. Further fibril separation then occurs owing to the absorption of the water present, producing swelling. The fibrils give us bonding properties; therefore it is important that they be exposed by beating or by chemical action. The fiber can thus be given controlled treatment which when all is said and done, determines to a great degree the characteristics of the finished product whether it be quality paper or paper for newsprint, bags, Christmas wrap, etc.

H. Project trans. 13.
   1. Explain distribution of uses of materials from the forest. Emphasize the fact that this graph will need constant revision as new substitutes for lumber are discovered and as new products from timber are developed.
   2. Emphasize the fact that nearly one-fourth of the timber cut each year is simply wasted.

Activities: Several activities have been suggested throughout the presentation of this unit. Some additional activities which may be of interest to students are as follows:

1. Write Timber Engineering Company, 1619 Massachusetts Avenue, N.W., Washington, D.C. Ask for their booklet of wood experiments
2. Encourage students to do individual research on some aspect of industrial materials. Insist on neatness and accuracy of reports.
3. Class discussion - relative merits of wood as compared with other raw materials.
4. Cut a small green twig - pound with a mallet. Notice how the woody fibers separate, as in the first step in making wood pulp. Small group or teacher could do this.
5. Obtain samples of the various plywoods and particle boards. Subject samples to various tests--strength, moisture absorption, density, fire resistance, decay, chemical resistance, etc. Some tests will be included - others suggested in A.S.T.M., No. 16.
6. Encourage students to perform experiments on their own.
7. Obtain some papreg for examination and testing. (paper soaked with resin and pressed) Needs no special finish, is not affected by salt water, does not splinter or tear when pierced.
8. Invite guest speakers
9. Encourage students to prepare slides of the various woods under consideration for projection by use of the bioscope. Use the "mechanical pulp method.' See if they can see any differences in the various wood fibers.
10. Encourage students to make particle board from scratch. Try several different adhesives under many conditions. Can the student arrive at any conclusions from this?
11. Encourage students to become familiar with a good reference book on industrial materials.

REFERENCES:

STUDENT:

1. "The Story of Pulp and Paper"
2. "The Story of Lumber and Allied Products"
3. People and Timber
4. "Trees for Tomorrow"

TEACHER:

1. Wood Handbook, No. 72, U.S. Dept. of Agriculture Forest Products Laboratory.
2. Engineering Materials Handbook - Mantell
3. The Story of Paper Making, Edwin Sutermaster
4. A Handbook of Paper making, Higham
5. Trees for Tomorrow, American Forest Products Industries Inc., 1816 N. Street, N.W. Washington 6, D.C.
6. Wood Technology: Constitution, Properties and Uses, Tiemann, H.D.
7. A.S.T.M., American Society for Testing and Materials, 1916 Race St., Phil., Penn., Part 16, June, 1967.
8. Materials Handbook - Brady.

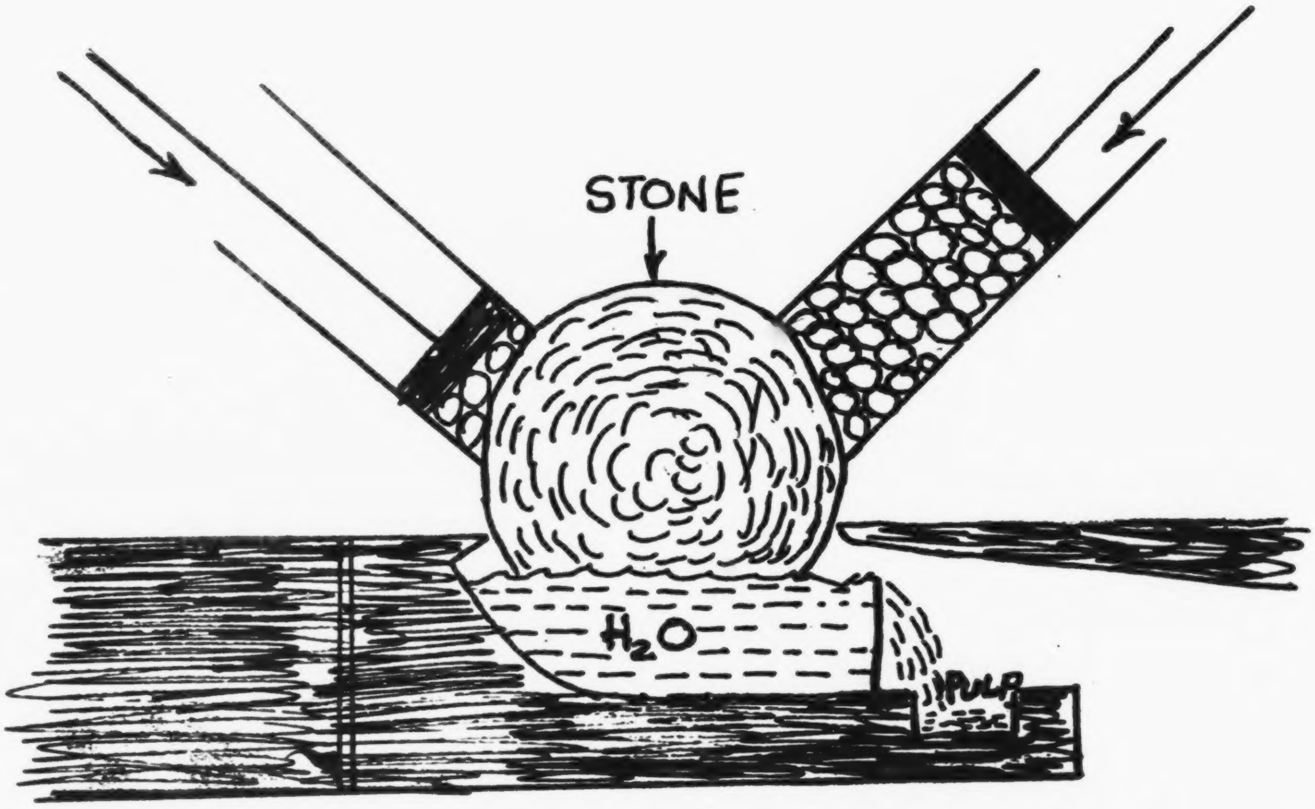
FOREST PRODUCTS

↓

BY - PRODUCTS

PULPWOOD
↓
WOOD PULP
↓
PULP

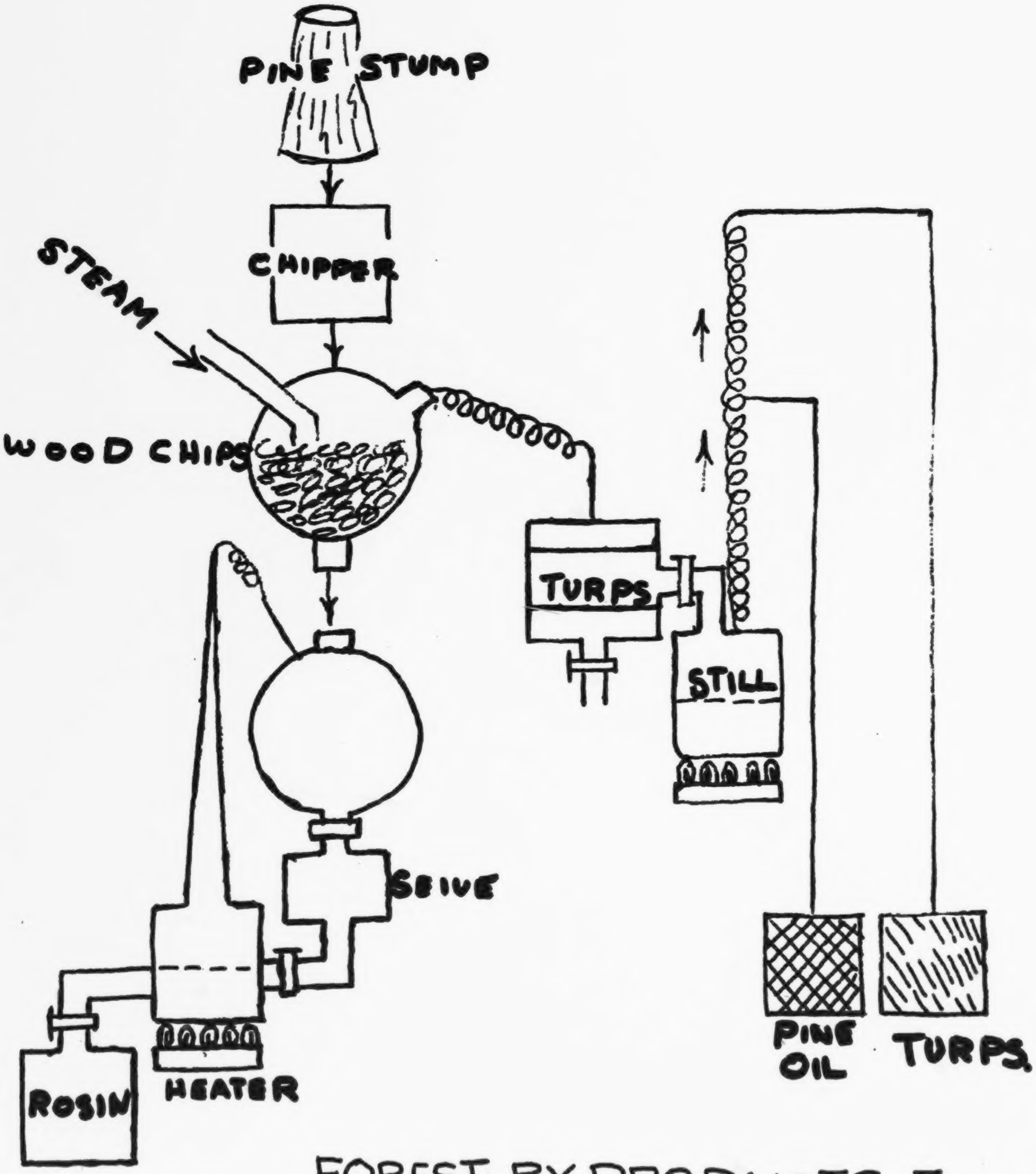
MECHANICAL PULP


STONE
H_2O
PULP

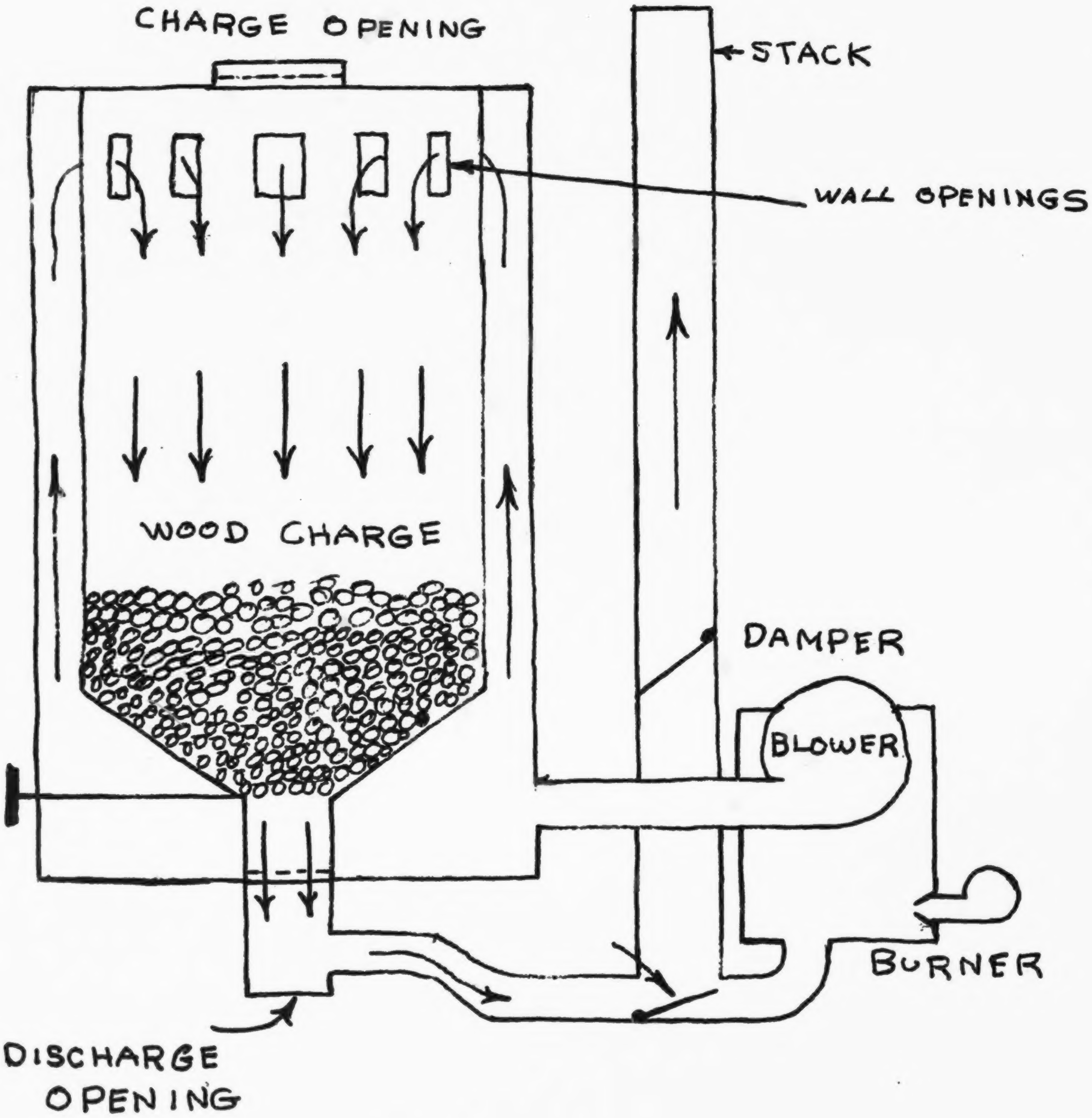
FOREST BY-PRODUCTS 3

EXTRACTIVES

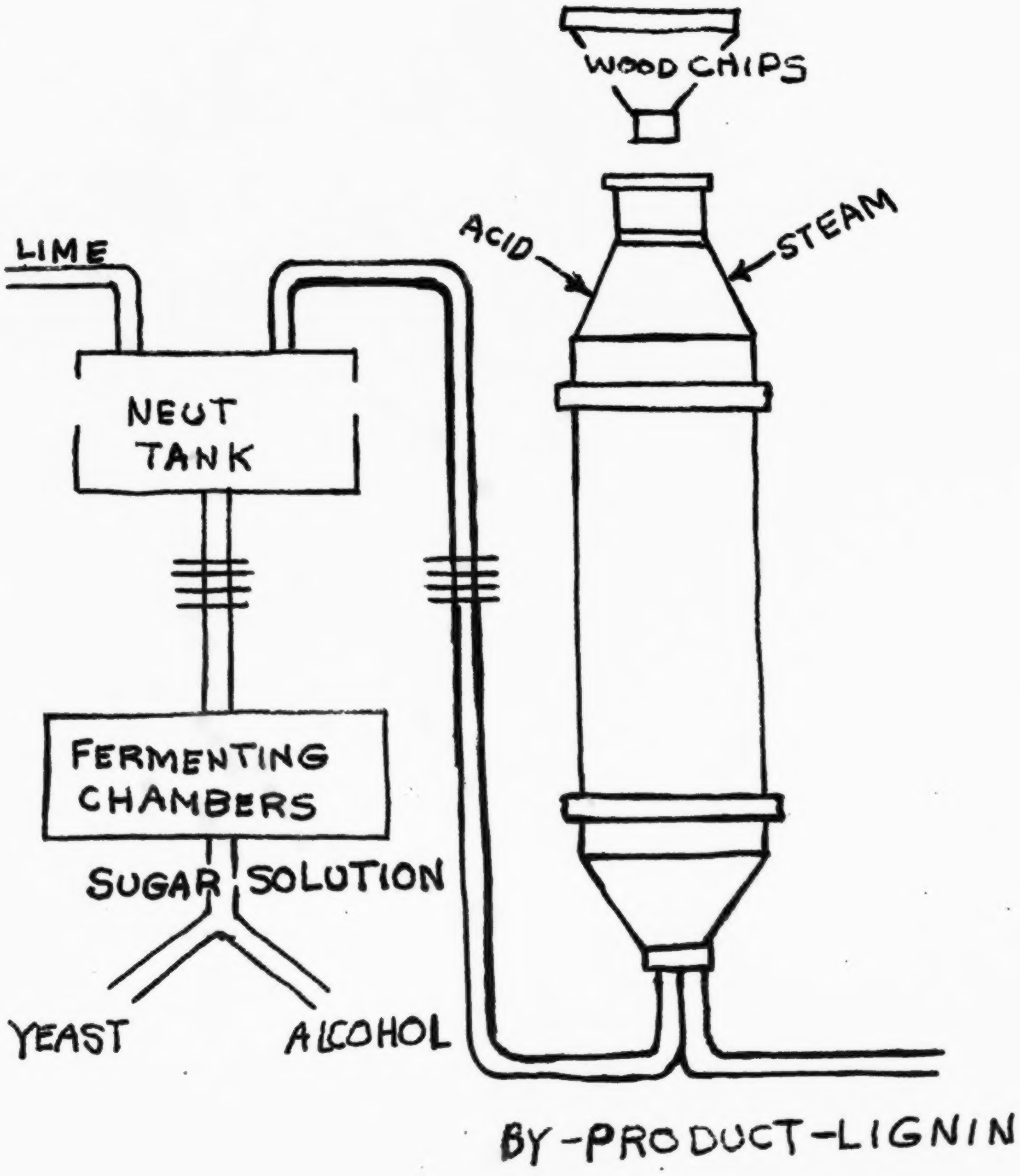
EXTRACTION


PINE STUMP
CHIPPER
STEAM
WOOD CHIPS
TURPS
STILL
SEIVE
HEATER
ROSIN
PINE OIL
TURPS.

DESTRUCTIVE DISTILLATION


CHARGE OPENING
STACK
WALL OPENINGS
WOOD CHARGE
DAMPER
BLOWER
BURNER
DISCHARGE OPENING

ACID HYDROLYSIS


WOOD CHIPS
ACID
STEAM
LIME
NEUT TANK
FERMENTING CHAMBERS
SUGAR SOLUTION
YEAST
ALCOHOL
BY-PRODUCT-LIGNIN

CHEMICAL ANALYSIS OF WOOD

CARBON	50.0%	BY WEIGHT OF DRY WOOD
OXYGEN	43.4%	BY WEIGHT OF DRY WOOD
HYDROGEN	6.0%	BY WEIGHT OF DRY WOOD
NITROGEN	0.1%	BY WEIGHT OF DRY WOOD
ASH (LARGELY SILICA)	0.5%	BY WEIGHT OF DRY WOOD

FOREST BY-PRODUCTS 10

BUILD UP OF A TREE

ATOMS

MOLECULES

MICELLES

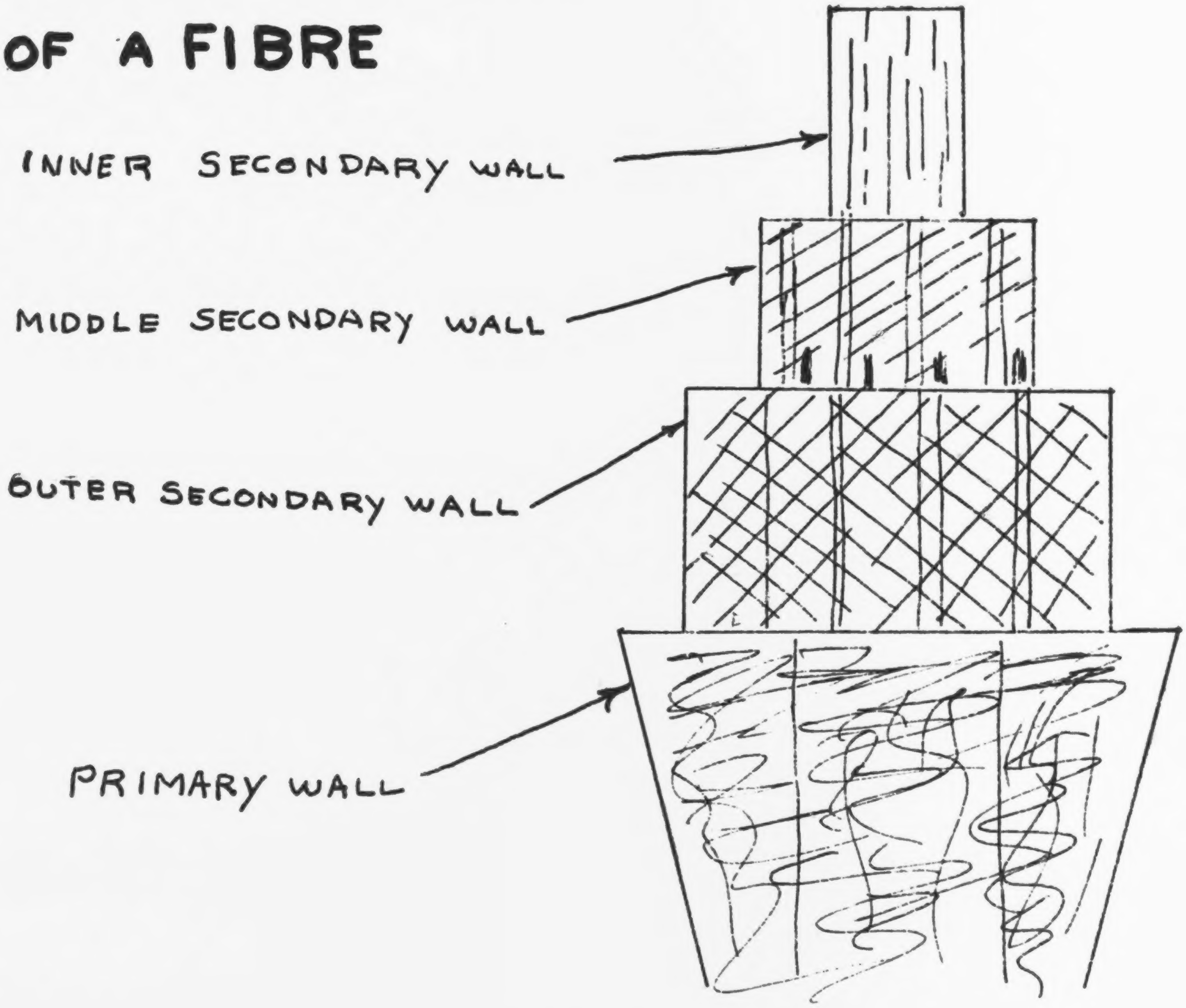
FIBRILS

FIBRE

PLANT

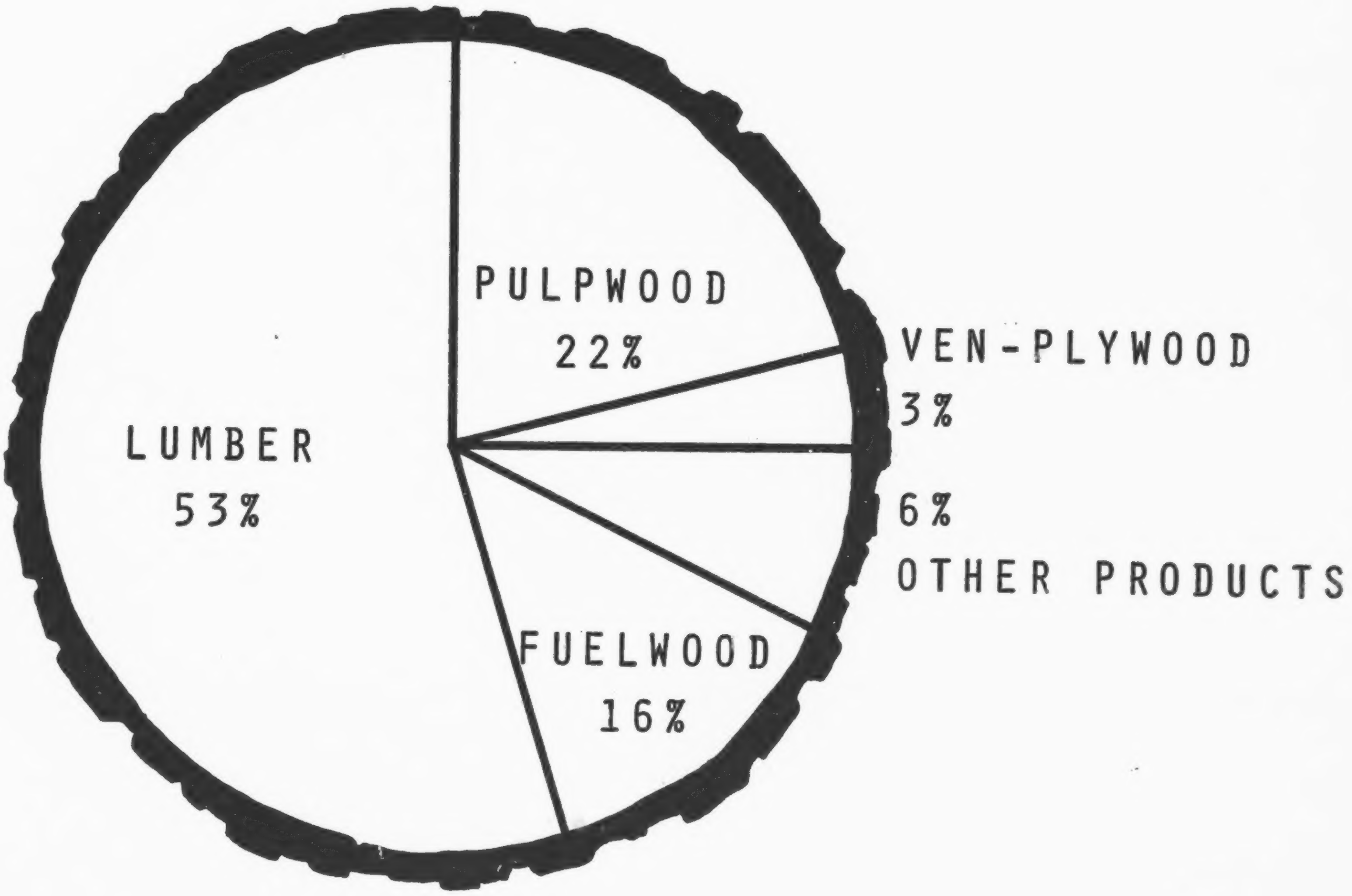
THE STRUCTURE

THE STRUCTURE OF A FIBRE


INNER SECONDARY WALL
MIDDLE SECONDARY WALL
OUTER SECONDARY WALL
PRIMARY WALL

THE STRUCTURE OF A FIBRE

FOREST By- PRODUCTS 12


PULPWOOD
22%
VEN-PLYWOOD
3%
LUMBER
53%
6%
OTHER PRODUCTS
FUELWOOD
16%

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Thayne McKnight
Grant Junior High
Denver, Colorado

INSTRUCTIONAL LEVEL: Junior High 7, 8, 9

TITLE: Introduction to Wood as a Material--A Review of Matter

PRESENTATION TIME: 1-3 45-minute class sessions

INTRODUCTION:

As we consider our environment, we see that we are surrounded with materials of all shapes, forms and fashions. All too often we accept these materials without asking where they come from, how we get them and how they are produced. Before any material can be considered as a usuable substance, we must investigate the nature of it with respects to matter and the natural principles governing all materials.

Wood is probably the oldest material that man has used for his benefit, yet man has for centuries been locked out of many of the secrets that would allow wood to be more beneficial.

In the consideration of wood as a material, we can learn how this material is constructed, what its characteristics are and how they may be utilized. It is important to realize however, that the nature of wood cannot be understood without a basic understanding of matter and its characteristics.

This unit attempts to present a review of the structure of matter and show how wood is a part of it in order for wood to be considered in more detail in further units of study.

OBJECTIVES;

1. To discuss in review the nature of matter.
2. To investigate the fundamental structure of materials.
3. To show the basic nature of wood as a material.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Wood Technology

INTER RELATION WITH OTHER SUBJECTS:

This unit may be usefully employed in any materials area of Industrial Arts with modification to meet the need of the particular area.

The basic material also relates to similiar material presented in science classes and may be used to support the instruction presented in this area.

USE IN INDUSTRY:

Since all materials are the combinations of matter and industry is primarily interested in the utilization of materials, it is only logical to assume that industry would have a great interest in the fundamental nature of the material that they are working with. This would in turn lead industry to research and development and the exploration of matter as it applies to them.

MATERIALS AND EQUIPMENT:

To present this lesson, the instructor will need an overhead projector, slide projector and demonstration models that the instructor chooses to build to illustrate the information.

EDUCATIONAL MEDIA:

This unit has been developed around overhead transparencies, but the use of slides, models and handouts is encouraged for further support of instructional material.

In the area of handouts, it is suggested that the student be given a printed summary of the information covered by the unit so that he has something for immediate and future review.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

This is primarily an academic unit with no particular hazardous operations involved; therefore, only normal I.A. precautions need be taken.

PRESENTATION:

The following is a suggested outline for the presentation of this basic science information as it relates to wood as a material. Since it is a suggestion, the instructor may need to alter it to meet his needs.

I. Introduction - previously stated
II. Definition of matter - Anything that has weight and takes up space
III. Composition of matter
    A. Neutrons
    B. Electrons
    C. Protons
    D. Nucleus

IV. State of matter
  A. Liquids - defined, example
  B. Solids - defined, example
  C. Gases - defined, example
V. Structure of matter
  A. Atom - definition, example
  B. Molecules - definition, example
  C. Compounds - definition, example
  D. Substances - definition, example
VI. Bonding of atoms
  A. Covalent bonding - definition, example
  B. Ionic bonding - definition, example
  C. Metallic bonding - definition, example
VII. Properties of matter
  A. Volume
  B. Mass
  C. Weight
  D. Elasticity
  E. Plasticity
  F. Toughness
  G. Ductility
  H. Malleability
  I. Organic
  J. Inorganic
VIII. Wood as matter
  A. Atomic nature of wood
    1. Compound - carbon, hydrogen, oxygen
    2. Molecular structure of cellulose
  B. Properties of wood
    1. Has weight, takes up space
    2. Is composed of atoms - compound nature
    3. Exists as a solid
    4. Has volume
    5. Has density
    6. Has weight
    7. Has toughness
    8. Is organic
IX. Review and reinforcement

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

This unit is primarily designed to be a review of material that the student has had in science classes and therefore the student should be familiar with most of its content. The instructor may choose any number of procedures for seeing that the student understands the information.

Included at the end of the unit is a series of short questions that will serve as a check of the students' understanding of the fundamental material.

UNIT EVALUATION:

This is an introductory unit that must be tailored to meet every particular situation. In order to evaluate it, the instructor may observe the response of the students and the knowledge that they display of the informtion. If the students find this material too "deep" the instructor may choose to reinforce it with further instruction and demonstration with other visual aids that will illustrate the fundamentals.

DEFINITION OF TERMS:

1. Atom - smallest particle of matter.
2. Molecule - smallest particle of a substance that retains the properties of the substance. The building blocks of all substances.
3. Compounds - Combination of two or more molecules of different elements.
4. Substances - any particular kind of matter that has its own specific properties.
5. Matter - anything that has weight and takes up space.
6. Solid - material that has fixed shape and volume.
7. Liquids - material that has no specific shape; takes the shape of its container. Has specific volume which seeks its own level.
8. Gases - has no specific shape; takes the shape of whatever container it is in. Has no fixed volume.
9. Volume - measure of space occupied by matter.
10. Mass - amount of matter a body contains.
11. Weight - measure of gravitational pull on a body.
12. Elasticity - having the ability to return to original shape.
13. Plasticity - the ability to take on new forms without rupture.
14. Toughness - resistance to breakage.
15. Ductility - ability to be drawn to shape.
16. Malleability - ability to be hammered to shape.
17. Organic - material from living organisms.
18. Inorganic - material from non-living substances.
19. Covalent Bonding - chemical bonding that depends on the sharing of electrons.
20. Ionic Bonding - chemical bonding that depends on the electrical attraction of oppositely charged ions that form a compound.

21. Metallic Bonding - bonding of atoms that depends on the free movement of the electron "gas" within the metal substance to provide bonding attraction between atoms.

REFERENCES:

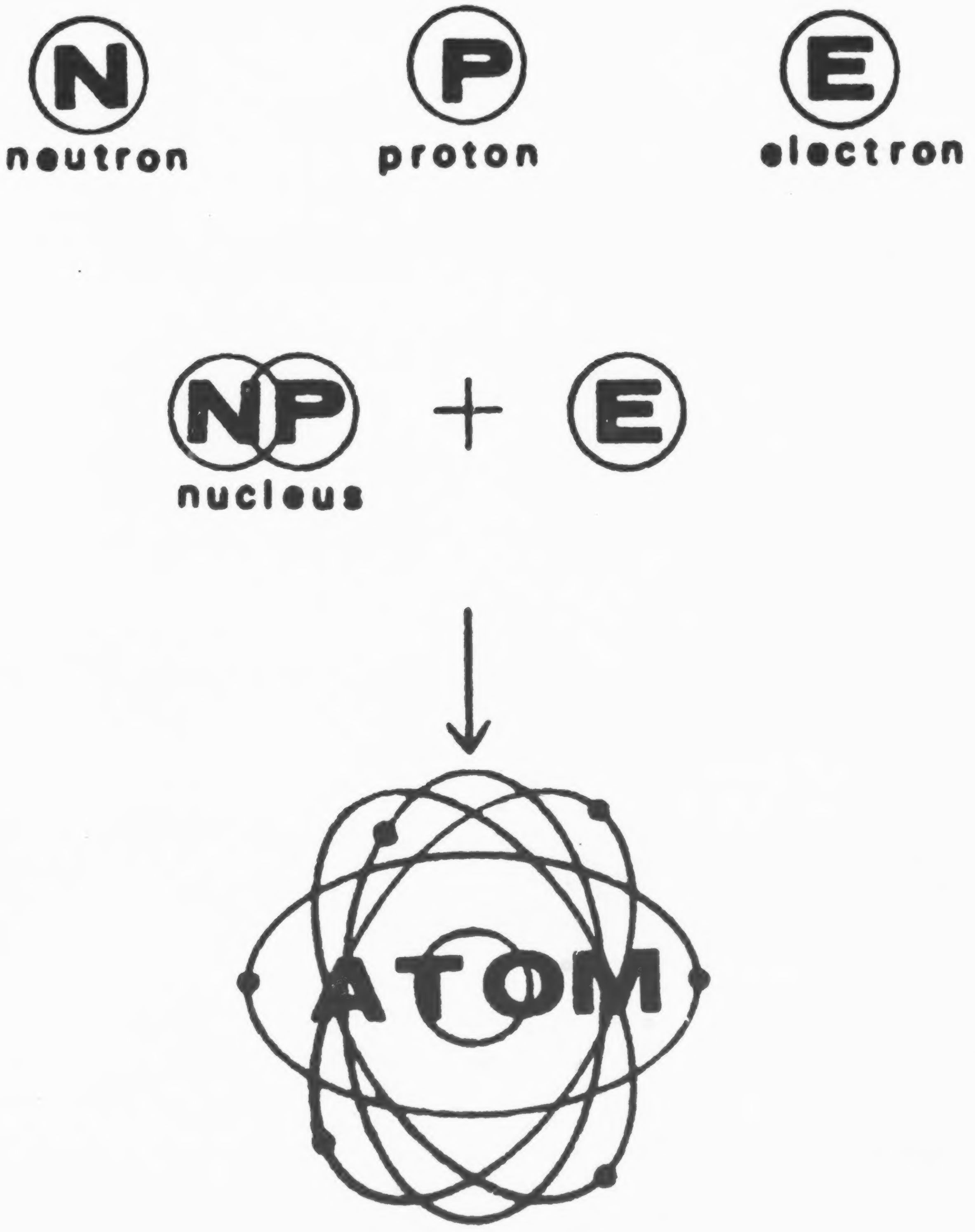
STUDENT:
1. Students' Science Textbook
2. Handout information issued by the instructor

TEACHER:
1. Science Teacher
2. Students' science textbook
3. Navarra, John, Zafforoni, Joseph, Carone, John. Today's Basic Science. California State Department of Education, 1967, pp. 23-75.

QUESTIONS TO BE ANSWERED BY THE STUDENT:

1. What is matter?
2. What is the basic composition of matter?
3. What are the basic states in which matter is found?
4. What makes the atoms of different elements react differently?
5. Define atom, molecule, compound, substance.
6. What is covalent bonding?
7. What is ionic bonding?
8. What is metallic bonding?
9. What are some of the properties that are used to describe matter?
10. What is the chemical composition of the wood molecule?
11. What is the chemical name for the molecular structure of the wood molecule?
12. What are some of the properties of wood that qualify it as matter?

MATTER



N neutron

P proton

E electron

NP + E

nucleus

ATOM

STATES OF MATTER

SOLIDS

LIQUIDS

GASES

STRUCTURE OF MATTER

ATOM

MOLECULE

COMPOUND

SUBSTANCE

m

PROPERTIES OF MATTER

VOLUME

MASS

WEIGHT

ELASTICITY

PLASTICITY

TOUGHNESS

DUCTILITY

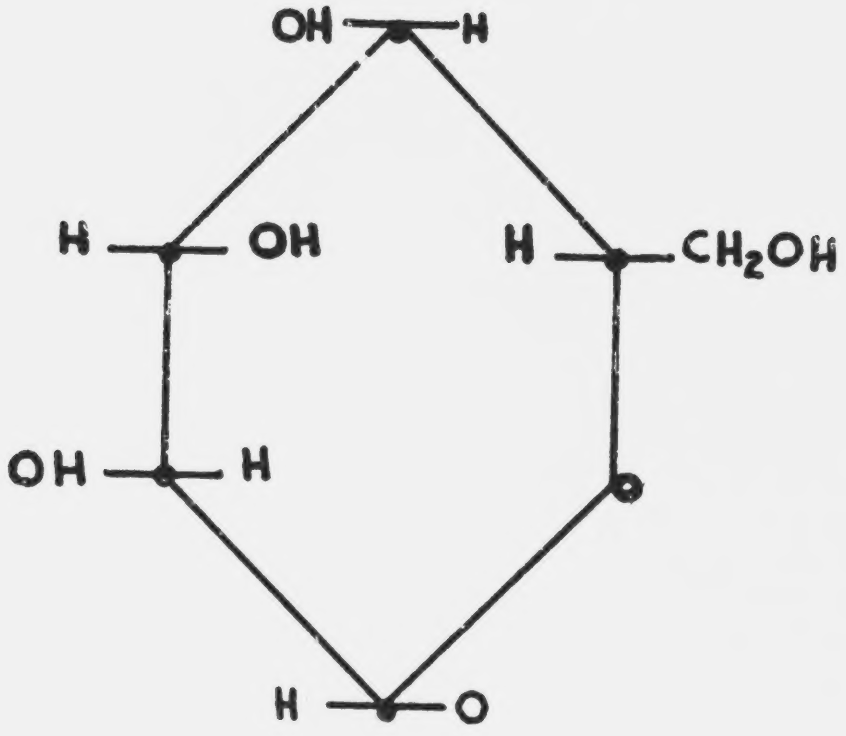
MALLEABILITY

ORGANIC

INORGANIC

WOOD AS MATTER

MATTER	WOOD
VOLUME	TxLxW
MASS	DENSITY
WEIGHT	POUNDS PER UNIT
TOUGHNESS	TOUGHNESS
ORGANIC	LIVING MATERIAL


OH
H
H
OH
H
CH_2OH
OH
H
O
H
O

CELLULOSE MOLECULE

CARBON OXYGEN HYDROGEN
COMPOUND

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Jim Peters
Caroline Davis Junior High
San Jose, California

Thayne McKnight
Grant Junior High
Denver, Colorado

INSTRUCTIONAL LEVEL: Junior High School

TITLE: Lumbering and Lumber

PRESENTATION TIME: 1 1/2 hours

INTRODUCTION:

Lumbering has always been one of the most fascinating and romantic of occupations. It has been glorified in song and story in our history. However, while some lumbering practices have not changed in the last 100 years, most lumbering has become mechanized and modernized into a highly efficient process. The actual methods of lumbering vary with geographic location and the size of the company. Generally speaking, however, the procedure includes modern tree farm management, cutting the trees, taking them to the mill, cutting the logs into lumber, and seasoning the lumber.

OBJECTIVES:

To become familiar with the many aspects of modernized tree farming techniques.

To study the several phases of lumbering from the felling of the tree to the cutting of finished lumber.

To realize the difference between and the advantages of the different cutting methods.

To understand the different methods of seasoning lumber and the advantages and disadvantages of each.

To become aware of the factors in determining structural strength of lumber.

To develop a thorough knowledge of wood as a material and the factors affecting this material.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Woodworking

INTER-RELATION WITH OTHER SUBJECTS:

Science becomes a very integral factor when talking about high yield forests and hybrid tree breeding. Mathematics is always important in a presentation of this sort. Just about every industrial arts subject area is affected because of the many applications of wood and wood products.

USE IN INDUSTRY:

This unit is basically a simplified study of industrial practices in the several areas covered. Concepts, men, automotive practices, materials, processes, and end products are involved in varying degrees. Lumbering is an old subject with a new approach and the implications are very important.

MATERIALS AND EQUIPMENT:

There isn't any special materials or pieces of equipment required. Various demonstrations can be conducted to illustrate the way green lumber cracks and warps if allowed to dry in an uncontrolled environment, wood - moisture relationships, and the compression and bending stresses on various grain arrangements

EDUCATIONAL MEDIA:

35 mm slide series
Slide projector

UTILIZATION IN THE TEACHING LEARNING ENVIRONMENT:

SAFETY:

There are no special safety requirements.

PRESENTATION:

Note: Title slides in the slide series correspond with the major numeral divisions in the presentation.

I. High Yield Forests
    A. The concept
        1. High yield forestry
            a. Most significant advance in timber management
            b. Move beyond passive reliance on nature's slow random pace of regrowth
        2. Computer-regulated trees
            a. Skilled men
            b. Highly sophisticated equipment
            c. One-third greater timber production than unaided land

3. Modern mechanized farm management
   a. Uses full range of agricultural sciences
   b. 50 year or more growing period
   c. Millions of acres
4. Forest management to:
   a. Meet rapidly increasing demands for building supplies, pulp, paper, packaging, and chemicals
   b. More wood from same land for more people--Faster!

B. The development
1. Many years of experience, imagination, planning and research
2. Years are little more than moments in forest evolution
   a. Up to 15 years to check seedling for superior traits of parent stock
   b. Longer wait for first harvest of new strain
3. Planning for optimum use of trees grown
   a. Consumer's past use
   b. Which of 5,000 products are needed most now
   c. What products are going to be needed in the future
      (1) Trees planted today mature decades from now

C. The men
1. Fertilize from the air (using aircraft)
2. Fight fires and harrow the forest floor
3. Foresters draw on professional skills of scientists who are specialists in:
   a. Forest pathology
   b. Wildlife biology
   c. Entomology
   d. Tree genetics and physiology
   e. Silviculture
   f. Forest soils
4. High yield forestry is a highly sophisticated program
   a. Professional training, high skill, and imagination are the qualities and requirements to run it.

D. The machines
1. Advanced machine design revolutionizes logging and forestry
2. Hydraulic shears can snip trees up to 18" in diameter for thinning the forest.
3. Machines are used to:

a. Carve out access roads for fire-fighting equipment
b. Remove underbrush from forest floor
c. Grapple and carry away entire truckloads of logs to speed handling.

E. The soil
1. Different soil types and landforms affect cultivation of timber
a. One typical tree farm reports 230 soil types and 60 basic landforms on their property (Weyerhaeuser)
2. Different tree species respond differently to same soil
3. There are many variables
a. Systems are devised so that land can be identified in terms of soil productivity

F. The trees
1. Genetics play a big part in producing superior trees
a. Straighter, taller, faster growth is possible through tree breeding
2. Hybrid trees are an important element in forest management routine
3. Special seed orchards have been developed over the last 25 years
a. From genetically superior orchard stock
b. Establishes second-growth tracts of vigorous, rapidly growing "supertrees"

G. The programming
1. High yield forestry began to emerge as a concept 30 years ago
2. Bit by bit, an enormous body of knowledge about the timber reserve began to accumulate
a. Over last three decades
b. The quantity of data tended to limit its general application
3. High-speed electronic computers were developed
a. Rapid recovery and correlation of data became possible
b. The library of knowledge could be used quickly and efficiently
c. Computers compress time
(1) Documented information about the past is used to simulate the future
(2) Mathematical models of timberlands are constructed as far ahead as 2080 A.D.
(3) 2018 A.D. timber yield can be estimated by fertilizing a given stand of timber tomorrow

4. Computers allow updating of management plans
H. The results
1. Ultimate capability of increasing total supply of wood fiber as much as 33 per cent
2. Demand is enormous
a. Decade estimate - world will need 42% more wood, wood fiber, and cellulose a year
3. Over 5,000 products produced
a. Plastics to particleboard
4. Parallel demand for land
a. Places where timber can be grown keeps diminishing
b. Rural land shrinks by a million acres a year
5. The United States can't afford to merely wait for wood to grow!
II. Lumbering
A. Cutting trees
1. Select site for logging camp
a. Provide working and living facilities
2. Mature trees are marked for cutting
a. Cut notch on side of tree toward desired fall line
3. Tree is cut with saw from opposite side of notch.
a. Wedge is driven in kerf
b. Branches are trimmed off felled tree
c. Logs are then stacked at loading site
B. Transporting logs to the mill
1. Years past
a. Logs moved to nearest river or stream in winter
b. Logs floated to mill in spring as the water rose
2. Today, logs are loaded onto trucks or railroad flatcars by crane
C. Lumber manufacture
1. Logs are moved from millpond to mill on a bullchain
a. Sprayed with water to clean dirt off log
2. Inside mill, each log is loaded on a carriage which holds it as it is being cut
3. The sawyer takes over
a. One of the most important men in the mill
b. Complete knowledge of lumber grades
c. Gets largest amount of high-quality lumber from each log

(1) By controlling the movement of the headrig (carriage and the headsaw) where logs are cut into boards or timber
(2) Small mills use circular saw as a headsaw...large mills use a bandsaw

4. Carriage moves log straight into saw
   a. Position of log is shifted for each cut
5. After log is cut to size, it is carried on by conveyors
   a. Other saws trim the bark off edges
   b. Cut log into standard sizes
      (1) Soft lumber - cut into standard dimensions in thickness, width, and length
      (2) Hardwoods - cut into standard thickness only to avoid expensive waste
         (a) The nature of hardwood use does not require standard lengths
6. An edger saws the boards into different widths
7. Trimmer saws cut to proper lengths
8. After seasoning
   a. Larger mills usually have a planer mill section
   b. Rough lumber is finished by planing
   c. Boards are made into building "trim"
   d. Separate planing mills buy rough lumber from small mills
      (1) Sell "surface lumber"
      (2) Finished lumber is again graded before shipped

III. Cutting Methods
   A. Two major ways of cutting lumber
      1. Plain-sawed (hardwood) or flat-grained (softwood)
         a. Cheapest and most economical
         b. Log is squared and sawed lengthwise from one side to the other
         c. Grain and annual rings are more parallel to cut of board
      2. Quarter-sawed (hardwood) or edge-grained (softwood)
         a. More expensive
         b. Shows better grain pattern in hardwoods
         c. Cut parallel to the medullary rays
         d. Rings are perpendicular to face of wood
         e. Prevents warpage
         f. Provides better wearing surface

IV. Seasoning
   A. Green lumber
      1. Fresh cut tree - 30-300% moisture by weight

- a. Moisture exists both inside cell cavity and cell walls
- b. A large part must be removed before wood can be used

B. Drying
- 1. Air drying
  - a. Stacks of lumber left in the open in sheds
  - b. Wood dries naturally over a period of several months
  - c. Much soft lumber is air-dried
  - d. Spacers between each board to permit air flow
- 2. Kiln drying
  - a. More efficient way of controlling moisture content
  - b. Dried artificially in a moisture-temperature room called a kiln
  - c. Woods allowed to dry several months
  - d. Then placed in a building made of cement brick or hollow tile
  - e. Stacks are first sprayed with steam, then the building is closed
  - f. Warm air is circulated through the lumber
    - (1) Continued till moisture content is down to 6-10% (2-8 days)
  - g. Kiln-dried lumber is the only satisfactory kind to use for furniture making
- 3. Free water in cell cavities is removed first
  - a. No shrinkage
  - b. Then at fiber-saturation point
    - (1) 23-30% moisture content
  - c. Water in cell walls then begins to evaporate
    - (1) Wood begins to shrink in size
    - (2) At 15% moisture, wood has attained 1/2 of its total shrinkage
- 4. House frame construction lumber - 19% moisture
- 5. Furniture construction lumber - 6-10% moisture

C. Shrinkage and swelling
- 1. Wood shrinks as it dries
- 2. Wood swells as it obtains moisture
- 3. Wood shrinks:
  - a. Tangential shrinkage - 4-14% (plain-sawed)
  - b. Radial shrinkage - 2-8% (quarter-sawed)
  - c. Lengthwise -.1-.2%
  - d. Volumetric - 7-21% (total of above)
- 4. More swelling along annual rings
  - a. Denser area for absorption

V. Structural Strength
   A. Bending load
      1. Strength of annual ring configurations
         a. Parallel to pressure (plain-sawed) -strongest (1)
         b. Convex to pressure (quarter-sawed) -middle (2)
         c. Concave to pressure (quarter-sawed)-weakest (3)
      2. Annual rings constitute densest area of wood
         a. Proper positioning of denser areas will create more resistance to pressure
   B. Compression load
      1. Strength of annual ring configurations
         a. Convex to pressure - strongest (1)
         b. Parallel to pressure - middle (2)
         c. 45 degree angle to pressure - weakest (3)
   C. Compression-tension distribution
      1. When pressure is exerted perpendicular to a board's edge:
         a. Compression on top edge
         b. Tension on bottom edge
            (1) In the first case, the molecules are jammed together and in the second case, the molecules are pulled or stretched longitudinally

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

Students should be involved during presentation to enhance their interest in the subject. Questions should be asked that will lead students from their personal experiences to an imaginative involvement with the presentation subject matter.

UNIT EVALUATION:

Students should be tested in each major division. If results are unimpressive in any one area, that area should be evaluated, reconstructed, and presented in this new light.

Student response should be noted during presentation. Tests should be constructed by each individual instructor using this unit to meet his own specific needs.

DEFINITION OF TERMS:

1. Mill - A building provided with machinery where the process of manufacturing lumber is carried on.
2. Millpond - A pond that supplies the water for a mill. Logs are kept in the millpond until they are to be cut to keep the moisture content in the logs high to prevent cracking and warping.

3. Bullchain - A chain or conveyor that carries the logs from the millpond into the mill.
4. Carriage - A device for holding the logs while they are being cut.
5. Sawyer - A highly qualified man, knowing all the grades of lumber thoroughly, whose job it is to saw the logs into lumber.
6. Headrig - A term meaning a combination of the carriage and the headsaw. The headsaw is the main saw used for cutting the log into squared lumber.
7. Kiln - A large, artificially heated chamber used for drying lumber.
8. Tangential - In the direction of a tangent. Having the same direction as the grain.
9. Radial - Characterized by divergence from the center.
10. Compression - Being pressed or squeezed together... denser.
11. Tension - State or degree of being strained to stiffness.
12. Entomology - The study of insects.
13. Pathology - The science treating of diseases, their nature, causes, etc.
14. Genetics - The branch of biology dealing with heredity and variation among their related organisms, largely in their evolutionary aspects.
15. Silviculture - The art of producing and caring for a forest.

REFERENCES:

STUDENT:

Woodworking Textbook

Breetveld, Jim. Treasures of the Timberlands. Scholastic Magazines Publications, 1967.

TEACHER:

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SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Buster K. Ichikawa
Roosevelt Jr. High
San Jose, California

INSTRUCTIONAL LEVEL: Jr. High

TITLE: Pencils, Its History, Manufacture, Properties and Hardness

PRESENTATION TIME: One Period

INTRODUCTION:

Pencils are taken for granted by most people. A draftsman, however, should have a basic understanding as to why and what determines the hardness of pencils. This unit will examine lead samples under the microscope to establish the relative graphite-clay composition. Microscope photos will be made into chart form showing at a glance the "gradation"from soft lead to hard.

OBJECTIVES:

1. To determine why a lead is soft or hard
2. To determine the composition of lead
3. To study the properties of graphite
4. To have the opportunity of using a microscope
5. To study the history of pencils
6. To gain an insight on the manufacturing of pencils

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Developed as a unit in drafting

INTER-RELATION WITH OTHER SUBJECTS:

Can be used in part or total in any other industrial arts subject area. Can be used in a science class.

USE IN INDUSTRY:

Research is the backbone of the industries. Companies are constantly seeking for ways to improve their products. Studies of this nature may develop a more uniform or durable pencil lead. Also not to be disregarded is the possibility of developing a useful by-product.

MATERIALS AND EQUIPMENT:
1. Overhead projector
2. Screen
3. Microscope
4. Samples of mounted lead

EDUCATIONAL MEDIA:
1. Transparencies
2. Charts
3. Lab. Sheets

UTILIZATION IN THE TEACHING LEARNING ENVIRONMENT:

PRESENTATION: (see encl. for complete write-up)
1. History
2. Manufacture Process of Pencils (transparencies)
    a. Graphite and clay ground and mixed into paste
    b. Into cylinder - piston forces through extrusion
    c. Cut into lengths - dried & baked (1600°-2200° F)
    d. Encased in wood
3. Properties of Graphite (transparencies)
    a. Graphite and diamond pure carbon (C)
    b. Comparison of physical properties
4. Quality and Hardness of Lead (chart)
    a. Quality and fineness of graphite and clay
    b. Hardness - ratio of clay to graphite
    c. Gradation by numerical system. 8B (softest) to 10H (hardest)
    d. Apparent hardness depends on size of small particles of lead deposited on paper. Particles are same blackness regardless of degree of hardness; only size and number determines how much of paper will be obscured.
5. Demonstration & Experimentation (lab work sheet)

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:
Lab work sheet (encl)

UNIT EVALUATION:
1. Determination of how well students performed on the lab work sheet questions
2. Follow up tests

3. Must be tried by the teacher and a subjective evaluation made

DEFINITION OF TERMS:

1. Hardness: resistance of a material to penetration of its surface
2. Electrical Conductivity: movement of electrical charge from one location to another
3. Specific Gravity: ratio of density of a material to density of water
4. Extrusion: shaping operation accomplished by forcing plastic material through die
5. Die: a forming tool
6. Abrasion: a wearing or rubbing away
7. Opaque: not allowing light to pass through
8. Translucent: partly transparent
9. Graphein: greek verb "to write"

REFERENCES:

STUDENT:

World Book Encyclopedia
Encyclopedia Britannica
Encyclopedia Americana

TEACHER:

Above, plus:

1. Brady, *Materials Handbook*
2. Clausen, Fabian, Peckner, Riley, *The Encyclopedia of English Materials & Processes*
3. English, *Getting Acquainted with Minerals*
4. Van Vlack, *Elements of Materials Science*
5. McGraw-Hill Encyclopedia of Science & Technology

PRESENTATION

A. History
   1. Ancient Egyptians used lead (Pb)
   2. Graphite first used as lead arount 1500
      a. First chunks called marking stones
      b. Later graphite sticks wrapped with strings and unwound for use as needed
      c. Pieces also pushed into tubes (forerunner of mechanical pencils)
   3. 1795, French Nicolas Jacques Conte mixed graphite and clay with water -- pressed into grooves in wood -- baked in kiln to fire clay
   4. 1795, Joseph Hardtmuth varied clay content -- varied hardness of lead
   5. 1839, Johann Lothar von Faber of Nurnberg improved Conte process by extruding paste through die
   6. Graphite - Greek verb graphein, "to write"

B. Manufacturing Process
   1. Graphite and clay ground and mixed into paste
   2. Into cylinder with die in bottom -- .070"-.170"
   3. Piston forces dough through extrusion
   4. Cut into lengths
   5. Dried and baked (1600° - 2200° F)
   6. Placed into wood with slots (2 halves)
   7. Glued (switched from hide glue to polyvinyl acetate emulsion adhesive about 1940's)

C. Properties of Graphite
   1. Pure carbon (C) same as diamond (C)
   2. Very soft - hardness of (1) compared to diamond hardness of (10)
   3. Relatively flexible; diamond brittle
   4. Conductor of electricity; diamond - non-conductor
   5. Specific gravity 2120; diamond 3.52
   6. Opaque, diamond transparent or translucent
   7. Greasy feel -- soft and will rub off on anything it touches

D. Quality and Hardness
   1. Quality and fineness of graphite and clay
   2. California incense cedar in better pencils -- others redwood or cedar
   3. Hardness-ratio of clay to graphite: more clay-- harder lead
   4. Graded by numbers - 8B (softest) to 10H (hardest)
   5. Degree of hardness -- measure of how much the lead resists abrasion by fibres of paper

   a. Apparent hardness of mark depends on size of small particles of lead deposited on paper
   b. Particles of same blackness regardless of degree of hardness; only size and number of particles determines how much of paper will be obscured

E. Demonstration and Experimentation
   1. Teach the use and care of a microscope
   2. Talk about how samples were prepared
   3. Have students observe samples in microscope and answer lab. work sheet

Process of Preparing Lead Samples For Microscopic Photo

1. Pencils of varying hardness from 6B to 9H
2. Cut off 1/4" from the ends of each pencil making certain to identify each piece (drafting tape)
3. Place and label each piece of sample on a piece of paper
4. Place a mold on the paper so that each lead sample is centered within the mold
5. Mix enough plastic for all of the molds. Ratio: 1 1/2 parts by volume of Plastic Powder to 1 part of Plastic Liquid
6. Pour this mixture into the molds and let set for at least 1/2 hour
7. Remove the plastic encased pencil leads from the molds
8. Prepare the samples for the microscope by sanding down from a 180 grit, 320 grit, to 600 grit silicon carbide wet paper. Using a hard fabric with an 800 mesh silicon carbide abrasive, work down to 1200 and then 3200 mesh.
9. The specimens are now ready for the microscope
10. Microphoto was taken at 100X with the time exposure set at 1 second on Kodak panatomic X film.

Comparative Hardness of Pencil Lead
Student Laboratory Work Sheet

1. From the chart, select sample 6B and 5B.

2. Focus these samples under the microscope.

3. Can you see dark and light particles? ________________

4. The dark particles are particles of ________________

5. The light particles are particles of ________________

6. Can you see any apparent differences between samples 6B and 5B in regards to the percent of dark and light particles? ________________________________

7. Select samples of 5B and 4B. Do you see any apparent differences? ________________________________

8. Now select samples 6B and 9H. Can you see any apparent differences in the percent of dark and light particles?
____

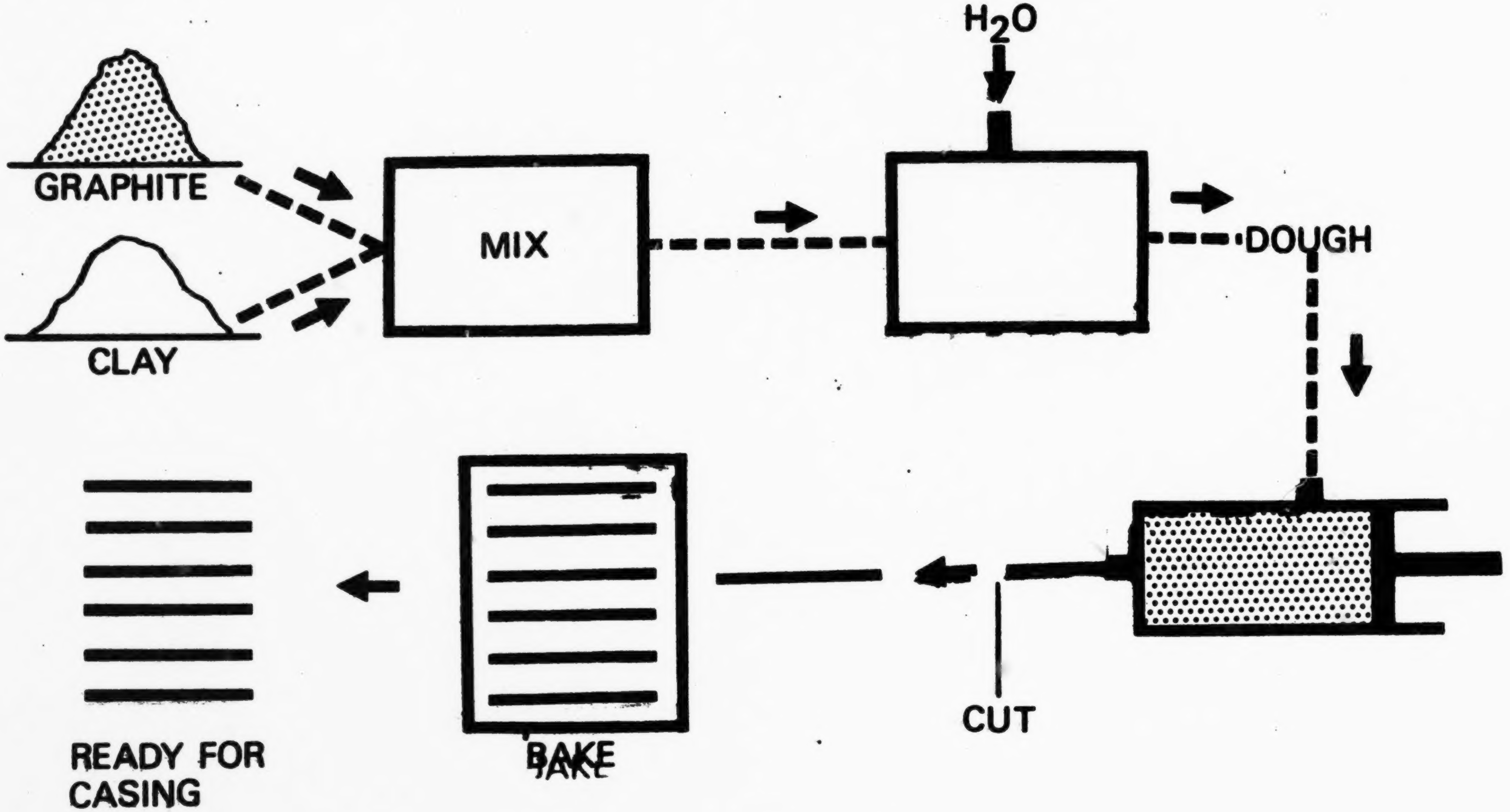
9. Which sample has more graphite? ________________

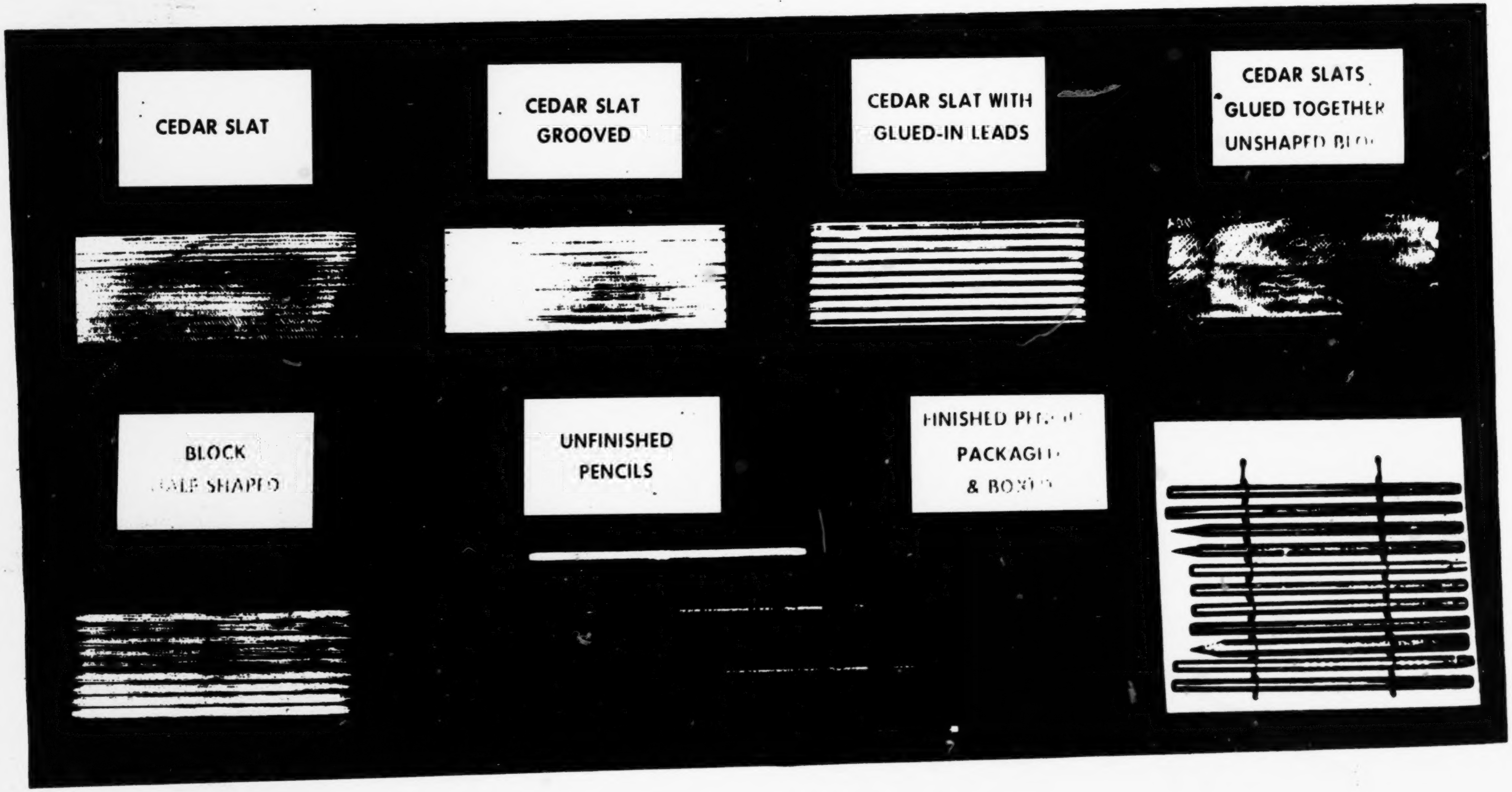
10. Which sample has more clay? ________________

11. Which sample is the harder pencil? ________________

12. Can you now complete the following sentence? A pencil lead is made from particles of graphite and __________. The(more - less) graphite particles, the harder the lead.

MAKING PENCIL LEAD


GRAPHITE
CLAY
MIX
H_2O
DOUGH
CUT
BAKE
READY FOR CASING

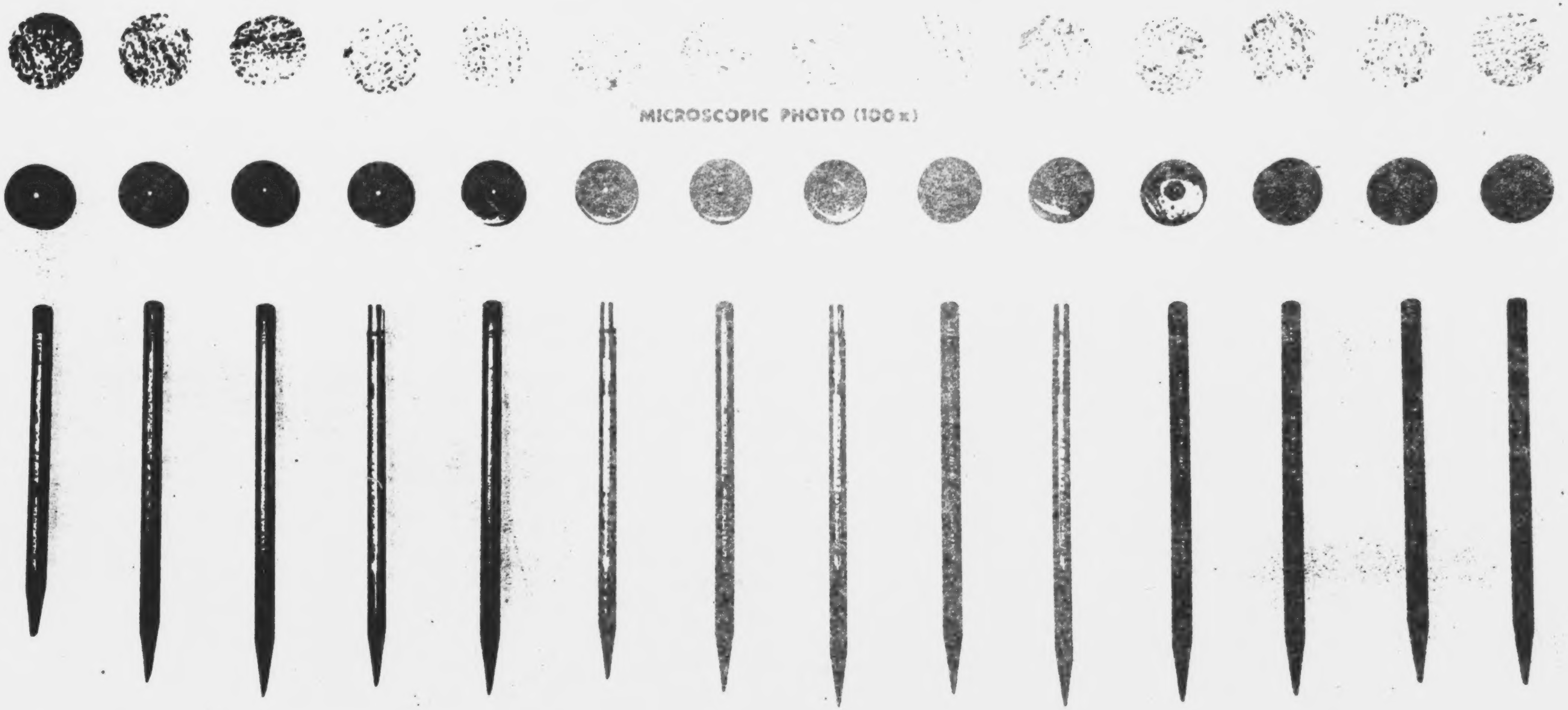

CEDAR SLAT
CEDAR SLAT GROOVED
CEDAR SLAT WITH GLUED-IN LEADS
CEDAR SLATS GLUED TOGETHER UNSHAPED BLOCK
BLOCK HALF SHAPED
UNFINISHED PENCILS
FINISHED PENCILS PACKAGED & BOXED

PROPERTIES OF GRAPHITE & DIAMOND

	GRAPHITE	DIAMOND
COMPOSITION	PURE CARBON	PURE CARBON
CHEM. SYMBOL	C	C
HARDNESS	VERY SOFT (1)	VERY HARD (10)
TENACITY	RELATIVELY FLEXIBLE	BRITTLE
CONDUCTIVITY	GOOD CONDUCTOR	NON-CONDUCTOR
LUSTER	METALLIC, DULL WHEN MASSIVE	ADAMANTINE, GREASY
SP. GRAVITY	2.20	3.52
TRANSPARENCY	OPAQUE	TRANSPARENT OR TRANSLUCENT

WHAT DETERMINES THE HARDNESS OF PENCILS

(PERCENT GRAPHITE & CLAY)


MICROSCOPIC PHOTO (100x)

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Robert Hoffer
Chowchilla High School
Chowchilla, California

INSTRUCTIONAL LEVEL: High School

TITLE: Properties of Wood

PRESENTATION TIME: The first presentation should be in one hour. It would then be up to the instructor if he wants to spend more time on any one of these parts for any part may be developed further.

INTRODUCTION:

Wood is used in an innumerable number of items and is formed in many ways thus developing by-products for use by man. Characteristics as open grain, closed grain, hardwood, and softwood are common methods of wood identification. One must in the total study of wood give some consideration to other properties generally grouped in the areas of physical, mechanical and chemical.

OBJECTIVE:

To show the physical, mechanical and chemical properties of wood.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Wood

INTER-RELATION WITH OTHER SUBJECTS:

The study of the properties of wood could appropriately be included in graphic arts when paper making is discussed. In science as a study to have the students become more aware of this common material that is used so much. In drafting as a material of construction. In plastics to show the many ways and combinations these materials are used.

USE IN INDUSTRY:

In industries today wood is cut, chipped, ground and formed into many products. For industries to produce the many products it does, the properties of wood must be thoroughly understood. In construction, the strength of wood must be understood. In paper making, the fibrous construction of the cell must be understood.

MATERIALS AND EQUIPMENT:

This unit is being developed as an overview of the properties of wood. It is therefore felt that no special materials will be needed. The instructor may want to develop a set of slides as he sees fit to parallel or complement the lecture.

EDUCATIONAL MEDIA:

These are to be developed into large posters and used during the presentation so students can follow easily.

Physical Properties

1. Density and Specific Gravity
2. Shrinkage
3. Thermal Properties
4. Thermal Conductivity
5. Coefficient of Thermal Expansion
6. Electrical Properties

Mechanical Properties

1. Properties of Clear Wood
2. Effect of Moisture Content
3. Effect of Specific Gravity
4. Effect of Duration of Load
5. Fatigue
6. Effect of Temperature

Chemical Composition and Properties

1. Chemical Components
2. Chemical Resistance
3. Combustion of Wood
4. Thermal Decomposition

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

I. Physical properties
   A. Density and specific gravity
      1. Specific gravity of wood = weight per unit volume
      2. Specific gravity of wood = weight of oven-dry per unit volume.
      3. Density of wood = specific gravity
      4. Solid material which cell wall is composed of has a specific gravity of about 1.5 regardless of species

B. Shrinkage
    1. Shrinkage occurs when hygroscopic moisture is removed from the cell walls of wood.
    2. Shrinkage is related to the amount of moisture removed below the fiber-saturation point.
    3. Tangential shrinkage 4-14%
    4. Radial shrinkage 2-8%
    5. Longitudinal shrinkage 0.1 - 0.2%
    6. Volumetric shrinkage 7-21% (The aggregate shrinkage occuring along all three axes).

C. Thermal Properties
    1. The specific heat of wood is related to its specific gravity
    2. The thermal capacity of moisture-containing wood is the specific heat of dry wood plus that of the included water.

D. Thermal Conductivity
    1. Thermal conductivity across the grain of wood ranges from 0.320 Btu/so ft/°F./in/hr. for balsa wood to 1.40 for dense hardwood.
    2. Conductivity parallel to the grain is two to four times as great as the transverse conductivity.
    3. Low-density woods heat more rapidly than high-density species.

E. Coefficient of Thermal Expansion
    1. Thermal expansion occurs in the three directions of wood as well as between species.
    2. Tangential direction 0.0000174 to 0.0000219 per degree F.
    3. Longitudinally 0.00000176 to 0.00000225 per degree F.
    4. Radially 0.0000120 to 0.0000179 per degree F.

F. Electrical Properties
    1. Dry wood has a high specific resistance to direct and low frequency alternating electric current.
    2. Oven-dry condition the volume resistivity of wood is in the range of $3x10^{17}$ to $3x10^{18}$ ohm-cm.
    3. There if little difference among species.
    4. Resistance drops with an increase of moisture below the fiber-saturation point.

II. Mechanical Properties
    A. Properties of clear wood
        1. The ratio of tensile strength parallel to the grain to that across the grain is 40-1.
        2. The ratio of compressive strength in these two directions is 7-1.
        3. The ratio of elasticity if 20-1 and may be as high as 150-1.

B. Effect of Moisture Content

1. Increase in strength begins when wood is dried below the fiber-saturation point.
2. Maximum crushing strength is doubled by drying to 12%
3. Most strength conditions are increased by drying

C. Effect of Specific Gravity

1. Strength properties of wood are dependent to a considerable degree upon its specific gravity

D. Effect of Duration of Load

1. The ability of wood to support a load is dependent on the duration
2. The longer the duration the greater the bend

E. Fatigue

1. When the wood is loaded repeatedly without reversal of stress, the endurance strength is higher than with reversed stress.

F. Effect of Temperature

1. Most strength properties of wood decrease at elevated temperatures and, conversely, increase at reduced temperatures
2. Shock resistance is an exception to the above
3. Permanent reduction in strength properties following exposure to high temperature indicates a deteriorating effect of heat on wood
4. Lower temperature can also be damaging if maintained for sufficiently long periods

III. Chemical Composition

1. Typical chemical - composition data on softwoods and hardwoods.

SPECIES	Ash	Holocellulose	Alpha cellulose	Lignin	Pentosans	Alcohol Benzene	Ether	1% NaOH	Hot water
	%	%	%	%	%	%	%	%	%
Western White Pine	0.3	64.3	42.3	25.4	7.9	8.3	5.6	15.6	3.7
Slash Pine	0.2	68.2	46.1	28.0	8.6	2.6	2.0	9.9	2.5
Western Hemlock	0.3	74.0	52.5	27.8	9.2	1.6	0.8	9.2	0.4
Aspen	---	78.9	50.1	19.2	18.7	2.8	1.1	17.2	1.5
Yellow Birch	0.8	72.5	51.0	22.7	22.6	2.6	0.8	15.4	2.7
Beech	0.5	75.7	51.2	21.0	20.2	1.8	0.7	14.7	1.5

TYPICAL CHEMICAL-COMPOSITION DATA ON SOFTWOODS AND HARDWOODS

B. Chemical Resistance
    1. Largely as a result of the chemical stability of cellulose, wood is highly resistant to the effects of air, light, water, corrosive smoke, and many chemicals.
    2. The most common cause of wood deterioration is decay, resulting from chemical attack by wood-destroying fungi. This will not occur, even in so-called nondurable woods, so long as wood is maintained at a moisture content below 20% or if it is water saturated.
    3. The darkening of wood on exposure to light is a superficial effect only.

C. Combustion of Wood
    1. Wood decomposes in the absence of air at temperatures above 525° F. The exact temperature depends upon the rate of heating.
    2. The heat value of dry wood expressed in B.T.U. per pound is relatively constant for all species.
    3. Resinous wood yield somewhat higher heat values than nonresinous woods.
    4. Because of their resin content and also in part owing to their higher lignin content, the fuel value of softwoods is generally calculated on the basis of a higher heat of 9,000 B.T.U. per pound and that of hardwoods as 8,500 B.T.U. per pound.
    5. The fuel value of a pound of green wood containing 80% moisture is only half that of dry wood.

D. Thermal Decomposition
    1. Rapid decomposition does not occur below the temperature of 525°F.
    2. Destructive distillation of hardwoods in the general temperature range of 525 to 950° F. results in the rapid decomposition of wood, yielding chiefly charcoal, acetic acid, methyl alcohol, tars, and such gases as CO, CO_2, H_2 and CH_4.

Tests for Properties of Wood (to be done by teacher as demonstration or by student as experiment)

1. Static bending
2. Fiber stress at proportional limit
3. Modulus of rapture
4. Modulus of elasticity
5. Work of proportional limit
6. Work to maximum load and total work
7. Impact bending

8. Fiber stress at proportional limit
9. Work to proportional limit
10. Height of drop causing failure
11. Compression parallel to grain
12. Fiber stress at proportional limit and maximum crushing strength
13. Compression perpendicular to the grain
14. Fiber stress at proportional limit
15. Tension parallel to grain
16. Tension perpendicular to grain
17. Hardness of end and side
18. Shear parallel to grain
19. Cleavage and toughness

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2. Brown, H.P., A.S. Panskin, and CC. Forsaith: Textbook on Wood Technology, Vol. 1 and 2, McGraw-Hill, 1949-1952.
3. Bureau of Standards: Lumber, Simplified Practice Recommendation, R16-53, U.S. Dept. of Comm. Wash., 1954.
4. Forest Products Laboratory: Kiln Certification, ANC Bull. 21, Government Printing Office, Wash, 1946.
5. Hansen, H.J., Timber Engineers' Handbook, Wiley, 1948.
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7. Vangaard, F.F., The Mechanical Properties of Wood, Wiley, 1950.
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SAN JOSE STATE COLLEGE
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1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY: Robert Hoffer
Chowchilla Union High School
Chowchilla, California

INSTRUCTIONAL LEVEL: High School

TITLE: Wood Abrasives

PRESENTATION TIME:

INTRODUCTION:

Abrasives are used very extensively in the woodworking industry as well as in related fields. The choice of quality and use is subject to such conditions as chemical composition, hardness, grain shape, and size, backing, and adhesives. It is important to show that these conditions exist and understand that these do have an effect on the appearance of the final product.

OBJECTIVE:

To become familiar with the minerals, backing, and adhesives used in coated abrasives.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Wood

INTER-RELATION WITH OTHER SUBJECTS:

This could be used in subject area fields such as metal, plastic, crafts, electricity-electronics, ceramics, and to a lesser degree in graphic arts and drafting where the abrasives for the abrasive purpose is used and where the study is from the materials point of view.

USE IN INDUSTRY:

The versatility and range of application of modern coated abrasives are much greater than most people realize. Coated abrasives are employed in the manufacture of almost every product used in the factory, office, and home and in air, marine, rail, and highway vehicles. The machines that made the machines or products were themselves usually brought to accurate and polished perfection with the aid of coated abrasives in one or more forms.

MATERIALS AND EQUIPMENT:

Samples of abrasive paper made of:

1. flint
2. emery
3. crocus
4. garnet
5. aluminum oxide
6. silicon carbide
7. abrasives made with: paper, cloth, vulconized fibers, combination of these fibers

EDUCATIONAL MEDIA

A. Slides of:
   1. flint
   2. emery
   3. garnet
   4. aluminum oxide
   5. silicon carbide
   6. flint under microscope
   7. emery under microscope
   8. garnet under microscope
   9. aluminum oxide under microscope
   10. silicon carbine under microscope

B. Board display as follows:

FLINT	SiO_2
EMERY	Al_2O_3,FeO
GARNET	SiO_2,FeO
CROCUS	FeO
ALUMINUM OXIDE	Al_2O_3
SILICON CARBIDE	SiC

C. The Story of Coated Abrasives, Society for Visual Education, 1345 Diversey Park, Chicago, Illinois 60611

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

- A. Introduction
  - 1. Coated abrasives consist of
    - a. flexible-type backing
      - (1) paper
      - (2) cloth
      - (3) vulcanized fibers
      - (4) combination of these materials
    - b. various types of adhesives
      - (1) resins
      - (2) hide glues
    - c. abrasives
      - (1) flint
      - (2) emery
      - (3) crocus
      - (4) garnet
      - (5) aluminum oxide
      - (6) silicon carbide
- B. Minerals
  - 1. Flint (SiO_2, Silicon dioxide)
    - a. a natural mineral
    - b. a quartz
    - c. fractures into a sharp-edge grain
    - d. 6.8 - 7.0 on the Mohs scale
  - 2. Emery (Al_2O_3, Impure corundum)
    - a. a natural mineral
    - b. grains are blocky
    - c. cuts slowly
    - d. tends to polish the material being abraded
    - e. 8.5 - 9.0 on the Mohs scale
  - 3. Crocus (FeO, Iron oxide hematite)
    - a. synthetic or natural
    - b. used in fine polishing and buffing operations
    - c. very soft-approximately 6 on the Mohs scale
  - 4. Garnet (SiO_2,FeO, Al_2O_3, Almondite)
    - a. a natural mineral
    - b. hardness and toughness is increased by heat treatment at high temperatures in a process controlled by color standards.
    - c. grains have very sharp edges
    - d. used in woodworking industry (dulls too rapidly for use in the metalworking field
    - e. 7.5 - 8.5 on the Mohs scale
  - 5. Aluminum Oxide (Al_2O_3, fused corundum)
    - a. produced in electric furnaces by purifying bauxite to a crystalline form and adding various amounts of titania to impart extra toughness

b. synthetic
c. 9.4 on the Mohs hardness scale
d. heavy wedge particles
6. Silicon Carbide (SiC, Moissanite)
a. synthetic
b. greenish black and iridescent
c. hardest and sharpest of synthetic abrasives
d. 9.6 on the Mohs hardness scale

C. Backing
1. Paper
2. Cloth
3. Vulcanized fiber
4. Characteristics
a. strength
b. adhesion
c. flexibility
d. weight

D. Adhesives
1. Glue
2. Resin
3. Varnish

E. Coating
1. Open coating (50-70% covered)
2. Closed coating (completely covered)

F. Flexing
1. Single-flex
2. Double-flex (two 45° angles)
3. Triple-flex (combination of single-flex and double-flex)

G. Grit sizes
1. Sizes
a. 12, 16, 20 extra coarse
b. 24, 30, 36 very coarse
c. 40, 50 coarse
d. 60, 80, 100 medium
e. 120, 150, 180 fine
f. 220, 240, 280 very fine
g. 320, 360, 400, 500, 600 extra fine
2. Explanation

The finest screen is No. 220 which means there are 220 openings to the inch in each direction, or 48,400 openings per square inch. Grains or "flours" finer than 200 are segregated by sedimentation or by air flotation. Grain sizes range from 12, the coarsest, to 600, the finest.

PRESENTATION:

- A. Introduction
- B. Objectives
- C. Inter-relation with other subjects
- D. Use in Industry
- E. Board display
  - 1. Flint
  - 2. Emery
  - 3. Garnet
  - 4. Crocus
  - 5. Aluminum Oxide
  - 6. Silicon Carbide
- F. Backing
- G. Adhesives
- H. Coating
- I. Flexing
- J. Grit sizes
- K. Slides
  - 1. Flint
  - 2. Flint under microscope
  - 3. Emery
  - 4. Emery under microscope
  - 5. Garnet
  - 6. Garnet under microscope
  - 7. Crocus
  - 8. Crocus under microscope
  - 9. Aluminum oxide
  - 10. Aluminum oxide under microscope
  - 11. Silicon carbide
  - 12. Silicon carbide under microscope

EVALUATION AND OBSERVATION

- A. Student performance
  - 1. Microscopic examination of prepared slides of flint, garnet, emery, aluminum oxide, and silicon carbide.
  - 2. Do research into the importance of abrasives in our industrial technology.

DEFINITION OF TERMS:

1. Abrasive - a graded grit in the form of flour, compound, or a coating on paper or cloth used in cutting and smoothing.
2. Flexing - controlled breaking of the continuous bonded abrasive coating with some detrimental effect on the bond or backing. The important feature of the flexing operation is to control the spacing and direction of the breaks.

3. Fracture - as the sharp edge of the grain is worn away by friction and pressure build-up, proper fracture characteristics cause the grain to refracture. This exposes a new cutting edge.
4. Grit sizes - the finest screen is No. 220 which means there are 220 openings to the inch in each direction, or 48,400 openings per square inch. Grains or "flours" finer than 220 are segregated by sedimentation or by air flotation. Grain sizes range from 12, the coarsest, to 600, the finest.
5. Hardness - the ability to penetrate an object.
6. Mohs scale - Mohs scale of hardness lists ten minerals of varying degrees of hardness. The scale was set up on the basis that No. 2 would abrade or scratch No. 1, No. 3 would abrade or scratch No. 2, etc.

   Mohs scale with materials:

   1. Talc
   2. Gypsum
   3. Calcite
   4. Fluorite
   5. Apatite
   6. Feldspar-orthoclase
   7. Quartz
   8. Topaz
   9. Corundum
   10. Diamond

REFERENCES:

STUDENT:

Coated Abrasives. New York: McGraw-Hill Book Company, 1958.
Wood Sanding with Coated Abrasives. Troy, New York: Behr-Manning Company.
Coated Abrasives Metalworking. Troy, New York: Behr-Manning Company.
Groneman & Glazener. Technical Woodworking. New York: McGraw-Hill Book Company.

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Coated Abrasives. New York: McGraw-Hill Book Company, 1958.
Wood Sanding with Coated Abrasives. Troy, New York: Behr-Manning Company.
Coated Abrasives Metalworking. Troy, New York: Behr-Manning Company.
Grone & Glazener, Technical Woodworking. New York: McGraw-Hill Book Company.
Abrasives-Their History and Development. Santa Clara, California: Norton Company.
American Society for Testing and Materials. Philadelphia, Pennsylvania.

SAMPLES AND DESCRIPTIONS OF COATED ABRASIVES FOR WOODWORKING

sample

1. Flint (SiO_2, Silicon dioxide)
   a. a natural mineral
   b. a quartz
   c. fractures into a sharp-edge grain
   d. 6.8 - 7.0 on the Mohs scale

sample

2. Emery (Al_2O_3, Impure corundum)
   a. a natural mineral
   b. grains are blocky
   c. cuts slowly
   d. tends to polish the material being abraded
   e. 8.5 - 9.0 on the Mohs scale

sample

3. Garnet (SiO_2, FeO, Al_2O_3, Almandite)
   a. a natural mineral
   b. hardness and toughness is increased by heat treatment at high temperatures in a process controlled by color standards
   c. grains have very sharp edges
   d. used in woodworking industry (dulls too rapidly for use in the metalworking field)
   e. 7.5 - 8.5 on the Mohs scale

sample

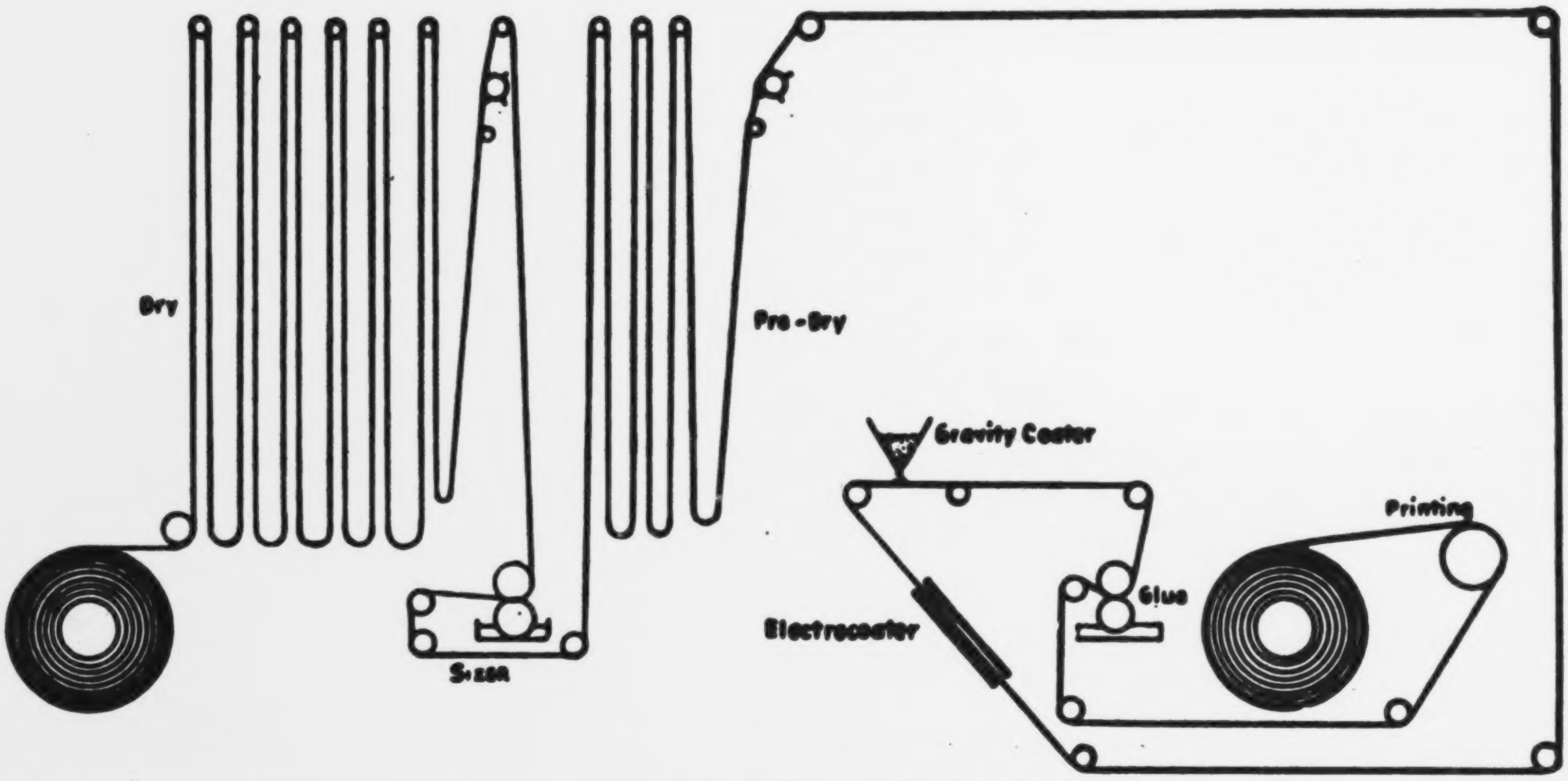
4. Crocus (FeO, Iron oxide hematite)
   a. synthetic or natural
   b. used in fine polishing and buffing operations
   c. very soft - approximately 6.0 on the Mohs scale

sample

5. Aluminum Oxide (Al_2O_3, fused corundum)
   a. produced in electric furnaces by purifying bauxite to a crystalline form and adding various amounts of titania to impart extra toughness
   b. synthetic
   c. 9.4 on the Mohs hardness scale
   d. heavy wedge particles

sample

6. Silicon Carbide (SiC, Moissanite)
    a. synthetic
    b. greenish black and iridescent
    c. hardest and sharpest of synthetic abrasives
    d. 9.6 on the Mohs hardness scale


Dry
Sizer
Pre-Dry
Gravity Coater
Printing
Glue
Electrocoater

DIAGRAMATICAL DRAWING shows the operations performed concurrently during a "run" or "make" of coated abrasives.

SAN JOSE STATE COLLEGE
INDUSTRIAL STUDIES DEPARTMENT
1968 NDEA INSTITUTE IN INDUSTRIAL MATERIALS

PRESENTED BY:	Thayne McKnight Grant Junior High Denver, Colorado	Jim Peters Caroline Davis Junior High San Jose, California

INSTRUCTIONAL LEVEL: Junior High -- 7, 8, 9 Wood Technology

TITLE: Wood and Moisture

PRESENTATION TIME: 1 to 3 45-minute class periods for lecture
4 to 5 15-minute class periods for demonstration

INTRODUCTION:

Wood is a hygroscopic material with such an affinity for water that it can safely be said that wood will always contain water unless desiccated to the point of chemical change. In view of this fact, it is necessary to the understanding of wood as a material that a student understand the relationship between water and wood and just how it effects the structure and characteristics of this material.

OBJECTIVES:

1. To discuss the relationship that exists between wood and moisture.
2. To investigate the chemical nature of wood.
3. To demonstrate the effects of moisture on wood.
4. To show how water in wood is utilized or discarded.

INTER-RELATION WITH OTHER SUBJECTS:

UNIT SUBJECT AREA: Wood Technology

INTER-RELATION WITH OTHER SUBJECTS:

This unit depends on a basic understanding by the student of the fundamentals of the nature of matter. It requires that the student be exposed to information that can be presented in the science class and therefore leaves the opportunity for close relations with this department.

USE IN INDUSTRY:

Since moisture plays such an important part in the basic composition of wood, it is only reasonable to expect that the industries involved with wood as a material would be interested in and very conscious of the wood-moisture relationships.

MATERIALS AND EQUIPMENT:

In the presentation of this unit, the instructor will need a variety of audio-visual equipment. The A-V aids with this unit are slides that may be shown with a slide projector. At the end of the unit there is a listing of suggested demonstrations and student experiments that will allow the student to better see much of the information presented in the unit.

EDUCATIONAL MEDIA:

This unit may be effectively presented with the use of slides, overhead transparencies, models, charts and demonstrations. The application of a slide series to present the basic information and student exercises to reinforce it has been employed by the author but the instructor may want to modify for his situation and talent.

UTILIZATION IN THE TEACHING-LEARNING ENVIRONMENT:

SAFETY:

This is a relatively hazard free unit except for some of the exercises that the student performs. The instructor should observe all normal lab safety precautions just as for any other lab experience to prevent accidents.

PRESENTATION:

The following is a suggested outline for the instructor to follow in the discussion of wood and moisture. It should be noted that this is only a suggestion and that the instructor is called on to modify this information to meet his needs.

I. Introduction
    A. Importance of wood as a material
    B. Review of the nature of matter
        1. Structure of matter
        2. States of matter
        3. Properties of matter
    C. Wood as matter
        1. Composition of wood
            a. Atomic Structure
            b. Components - carbon, oxygen, hydrogen
        2. Properties of wood
        3. Affinity for moisture
II. Nature of wood
    A. Molecular structure
        1. Hydrocarbon nature
        2. Sorptive nature - tendency of wood to absorb and desorb water according to the environment.
        3. Sorptive surfaces

a. External surfaces
b. Surface area of the cell cavities
c. Surface areas of the fibers in the cell walls

B. Physical structure
1. Cells
2. Fibers
3. Lignin
4. Cellulose
5. Cambium
6. Phloem
7. Medullary rays

III. Conditions where moisture occurs in wood

A. Free water - water that is contained in the cell cavities and intercellular spaces

B. Bound water - located within cell walls, separating the submicroscopic structural components but not absorbed by them. This water is bound by the attraction of the hydroxyl HOH to the OH portion of the cellulose molecule. It may be removed without chemically altering the wood.

C. Water of constitution - this water is part of the organic nature of the wood and is not removable without altering the nature of the wood.

D. Fiber saturation - condition describing the cell walls when they are thoroughly saturated with bound water but the cell cavities are void of free water.

E. Moisture equilibrium - the moisture content that wood will assume when exposed to a constant temperature and relative humidity.

F. Sap - natural moisture in wood that contains minerals, resins and food for the tree plant.

IV. Diffusion of water

A. Channels for diffusion
1. Inner communicating cell canals
2. Inner cellular spaces
3. Pit membrane channels
4. Transcient cell wall capillaries

B. Diffusion verses moisture content
1. Diffusion is impossible at saturation.
2. Diffusion may exist between saturation of cavities and saturation point of fibers.

C. Rate of diffusion - governed by moisture present, density and temperature.

D. Practical water movement in wood
1. Mechanic of water movement
a. Capillarity
b. Differences in water vapor pressure
c. Inequalities in concentration of liquid and water vapor.

2. Diffusion takes place faster with the grain and along the direction of sap flow than at right angles to it.

V. Effects of moisture on wood
  A, Absorption - taking in water, determined by density of cells. More water will be absorbed by dense cell structures.
  B. Expansion - when moisture is taken into the structure of the wood fiber it will swell causing a change in the dimensions of the wood.
  C. Shrinkage - process of growing smaller
    1. Tangential shrinkage -- 4-14%
    2. Radial shrinkage -- 2-8%
    3. Longitudinal shrinkage -- .1-.2%
    4. Volumetric (combination of the above) 7-21%.

VI. Removing moisture from wood
  A. Air drying
  B. Kiln drying

VII. Calculating moisture content of wood
  A. Electrical moisture meter
  B. Mathematical

$$\text{M. C. in per cent} = \left(\frac{W - D}{D} \right) 100$$

where: W=weight of moist wood
D=weight of wet wood

VIII. Generalities concerning moisture in wood
  A. As moisture content increases, weight increases
  B. As water is reduced below the fiber-saturation point, most strength properties will increase. Shock resistance is lowered by decrease in moisture content.
  C. Loss of moisture below the fiber saturation point causes shrinkage.
  D. Wood will swell until all parts of it have reached the fiber saturation point. Further increase in moisture content do not increase the dimensions of the wood.
  E. As moisture content increases, the thermal conductivity of wood increases.
  F. The dielectric properties of wood vary in proportion to the quantity of water held by the wood.
  G. Freshly cut trees may contain 30-300% moisture.
  H. Saturated wood is 20-30% by weight water.
  I. 7-12% is the normal range for furniture and construction woods.

IX. Review

EVALUATION AND OBSERVATION:

STUDENT PERFORMANCE:

It is suggested that the performance of the student be determined by written examinations as well as actual involvement in the activities suggested at the end of the unit for the student. The test used will depend on the instructor and situation and should be made accordingly.

UNIT EVALUATION:

Since this is a suggested unit for the instructor to follow, it may be desirable to change it to meet specific needs. The real evaluation of this unit is the student's understanding of the material. This unit is not complete and therefore allows for further expansion of technical data as well as visual aids to illustrate the information.

DEFINITION OF TERMS:

1. Moisture - water causing a slight wetness or dampness.
2. Hygroscopic - attracting or absorbing moisture from the air.
3. Adsorption - to suck in, drink in; to engulf wholly.
4. Cells - a compartment, or small hollow cavity in plants.
5. Fibers - a slender, threadlike structure that combines with others to form tissues.
6. Lignin - material that acts as bonding agent wood cells.
7. Cellulose - substance that composes the cell walls of a woody plant; a carbohydrate of unknown chemical structure.
8. Capillary - very small tubes present in the wood structure that act as transportation vessels.

REFERENCES:

STUDENT:

1. Handout information given to the student
2. Student textbook.

TEACHER:

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2. Forest Product Laboratory. Forest Products Lecture Outline on the Properties of Wood. Forest Service, U. S. Department of Agriculture, Washington, D.C., 1961.
3. Van Vlack, Lawrence H. Elements of Material Science, Reading, Massachusetts, Addison Wesley Publishing Co., Inc., 1959.

4. American Society for Testing Materials. Structural Sandwich Construction; Wood; Adhesives. Vol. 16., Philadelphia, 1967.
5. U.S. Department of Agriculture. Wood Handbook #72. U.S. Government Printing Office, Washington, D.C., 1955.

STUDENT EXERCISES AND DEMONSTRATIONS:

Listed below are some simple examples of experiments that may be done to illustrate some of the prominent facts concerning wood and moisture.

1. Absorption-expansion characteristics of wood fibers.
A small amount of wood shaving may be pressed to 6000 lbs. psi or to a less degree if heavy equipment is not available. The resulting pellets may be used to demonstrate how wood fibers will absorb water and in so doing will expand with great force. The compressed pellets should be about 1" in diameter and 1/2" in thickness for best results. If the pellets are placed in a small water container and water is added, the pellet will immediately begin to swell. If the size of the pellet is marked on the container, a comparison will show an increase in size. A pressure measuring device may be placed on the top of the pellet before the addition of water for the purpose of measuring the amount of pressure generated by the absorption process.

2. Change in dimension due to moisture.
In order to demonstrate how moisture effects the size of specific wood samples, the instructor or student may run a controlled experiment on these samples by measuring the pre-moisture state, the saturated state and the dried condition of each of the samples. A comparison of the results will show the effect that moisture will have under these conditions.

3. Moisture weight relationship.
In order to demonstrate how moisture will effect the weight of wood, the instructor may procede as in the above experiment with the exception of the comparison of the weight of the wood samples rather than the size.

4. Moisture effects on strength, bending, impact resistance and other physical properties.
The instructor will find that there are many simple ways that the student may compare the above mentioned characteristics of selected samples of wet and dry pieces of wood. These tests will require some simple testing mechanisms that have appropriate standards to measure weight, pull and force.

QUESTIONS FOR STUDENT REVIEW

The following is a list of questions that the student should be able to answer after being exposed to the unit.

1. What is the basic structure of wood and how does it relate to matter?
2. What is the basic compound of the wood molecule?
3. Why is the relationship of moisture and wood so important in the study of wood as a material?
4. What causes wood to have such an attraction for water?
5. What effects does the absorption of water have on wood?
6. How is the water diffused in the woody material?
7. What effect does the loss of water have on wood as a material?
8. What are the two methods for drying wood?
9. How is moisture content in wood calculated?
10. What is the relationship between the loss of water in wood and the grain pattern?